OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. ☒ Analysis — Check all that apply

Type of Analysis: ☐ Engineering ☒ Performance Assessment ☐ Scientific

Intended Use of Analysis: ☐ Input to Calculation ☒ Input to another Analysis or Model ☒ Input to Technical Document ☒ Input to other Technical Products

Describe use:

Develop EBS FEP Identification methodology

Select FEPs for TSPA modeling and analysis of the EBS

Provide Input to the EBS PMR and YM FEP Database

3. ☐ Model — Check all that apply

Type of Model: ☐ Conceptual Model ☐ Abstraction Model ☐ Mathematical Model ☐ System Model ☐ Process Model

Intended Use of Model: ☐ Input to Calculation ☐ Input to another Model or Analysis ☐ Input to Technical Document ☐ Input to other Technical Products

Describe use:

4. Title:

Engineered Barrier System Features, Events, and Processes

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-WIS-PA-000002 REV 01

6. Total Attachments: 1

7. Attachment Numbers - No. of Pages in Each:

Attachment I – 30 pages

		Printed Name	Signature	Date
8.	Originator	Peter K. Mast	Pet K. Mast	2/15/01
		George E. Barr	GE Barr	15 Feb '01
9.	Checker	Bruce T. Stanley	Bruce T. Stanley	2/15/01
10.	Lead/Supervisor	E. James Nowak	EJ Nowak	2/15/01
11.	Responsible Manager	Robert J. MacKinnon	Robert J MacKinnon	02/15/01

12. Remarks:

This revision of the AMR incorporates the EBS FEPs information developed in ANL-EBS-MD-000035, authored by G.E. Barr and O.E. Lev. The roles of the originators for this revision of the AMR are:

P.K. Mast – Lead originator and responsible for FEPs screening

G.E. Barr – EBS FEPs identification process

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ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

Page: 1 of: 231

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Engineered Barrier System Features, Events, and Processes

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ANL-WIS-PA-000002 REV 01

4. Revision/Change No.	5. Description of Revision/Change
00	Initial Issue
00/ICN 01	Changes to address the no backfill option.
01	Incorporate the EBS FEP identification process from ANL-EBS-MD-000035. As a result of this change to merge the two AMRs, the title was changed to eliminate the reference to abstraction. Also adds discussion of relevant secondary FEPs associated with all primaries.

CONTENTS

Page

FIGURES

TABLES

ATTACHMENTS

ACRONYMS AND ABBREVATIONS

AMR	Analysis/Model Report
CFR	Code of Federal Regulations
CLST	Container Life and Source Term
CRWMS	Civilian Radioactive Waste Management System
CSNF	Commercial Spent Nuclear Fuel
DE	Disruptive Events (PMR)
DHLW	Defense High Level Waste
DIRS	Document Input Reference System
DSNF	Defense Spent Nuclear Fuel
DOE	United States Department of Energy
DRKBA	Discrete Region Key Block Analysis
EBS	Engineered Barrier System
ENFE	Evolution of the Near-Field Environment
EPA	United States Environmental Protection Agency
FEPs	Features, Events, and Processes
FR	Federal Register
HLW	High-Level Waste
IA	Igneous Activity
IRSR	Issue Resolution Status Report
LADS	License Application Design Selection
M&O	Management & Operating (Contractor)
NEA	Nuclear Energy Agency of the Organization for Economic Co-Operation and Development
NFE	Near-Field Environment (PMR)
NRC	U.S. Nuclear Regulatory Commission
OECD	Organisation for Economic Co-Operation and Development
OCRWM	Office of Civilian Radioactive Waste Management
P&CE	(EBS) Physical & Chemical Environment (AMR)
PDD	Project Description Document
PMR	Process Model Report

ACRONYMS AND ABBREVIATIONS (Continued)

QAP	Quality Assurance Procedure
QARD	Quality Assurance Requirements and Description
RDTME	Repository Design and Thermal-Mechanical Effects
RN	Radionuclide
RT	Radionuclide Transport
SDD	System Description Document
SDS	Structural Deformation and Sesmicity
SZ	Saturated Zone
TBV	To-Be Verified
TEF	Thermal Effects on Flow
TH	Thermal-Hydrologic
TSPA	Total System Performance Assessment
TSPA-SR	Total System Performance Assessment Site Recommendation
UDEC	Universal Distinct Element Code
USFIC	Unsaturated and Saturated Flow Under Isothermal Conditions
UZ	Unsaturated Zone (PMR)
YM	Yucca Mountain Project
YMP	Yucca Mountain Site Characterization Project
WD&R	Water Distribution Removal (AMR)
WF	Waste Form (PMRs)
WF Misc	WF Miscellaneous (PMR)
WF Clad	WF Cladding (PMR)
WF Col	WF Colloids (PMR)
WIPP	Waste Isolation Pilot Plant
WP	Waste Package

ABBREVIATIONS

Ka	thousand years (before present)
km	kilometer
k.y.	thousand years (duration)
m	meter
Ma	million years (before present)
M_L	earthquake magnitude
mm	millimeters
MPa	mega Pascals (a unit of pressure)
MWm^{-2}	megaWatts/meter^2 (a unit of heat flux)

ABBREVIATIONS (Continued)

m.y.	million years (duration)
yr	year

1. PURPOSE

Under the provisions of the U.S. Department of Energy's (DOE's) *Revised Interim Guidance Pending Issuance of New U. S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada* (Dyer 1999; and herein referred to as DOE's interim guidance), the DOE must provide a reasonable assurance that the regulatory-specified performance objectives for the Yucca Mountain project can be achieved for a 10,000-year post-closure period. This assurance must be demonstrated in the form of a performance assessment that: (1) identifies the features, events, and processes (FEPs) that might affect the performance of the geologic repository; (2) examines the effects of such FEPs on the performance of the geologic repository; (3) estimates the expected annual dose to a specified nearby population group. The performance assessment must also provide the technical basis for inclusion or exclusion of specific FEPs.

Although the NRC has not defined or used the term "scenario" in the pertinent regulations, the Yucca Mountain Total System Performance Assessment (TSPA) has chosen to satisfy the above-stated performance assessment requirements by adopting a scenario development process. This decision was made based on the Yucca Mountain TSPA adopting a definition of "scenario" as not being limited to a single, deterministic future of the system, but rather as a set of similar futures that share common FEPs. The DOE has chosen to adopt a scenario development process based on the methodology developed by Cranwell et al. (1990) for the NRC. The first step of this process is the identification of FEPs potentially relevant to the performance of the Yucca Mountain repository; the second step includes the screening of each FEP.

The primary purpose of this Analysis/Model Report (AMR) is to document the identification, analysis, and screening decisions pertaining to certain FEPs, for inclusion in or exclusion from TSPA scenarios. 88 FEPs that have been identified as Engineering Barrier System (EBS) FEPs from the Yucca Mountain (YM) FEP Database (CRWMS M&O 2000gg) were subjected to screening (see Sections 1.1, 1.2, 1.3, and 1.4). This AMR provides input to the EBS Process Model Report (PMR) and the Database. This AMR and the Database are intended to document FEP definitions and screening arguments to assist reviewers during the license application review process.

1.1 SCOPE

This AMR has been prepared to satisfy the FEP documentation requirements addressed in the Work Scope/Objectives/Tasks sections of the work activity plan entitled *Technical Work Plan for Subsurface Process Modeling FY 01 Work Activities* (CRWMS M&O 2000ll).

The current YM FEP Database (CRWMS M&O 2000gg), herein referred to as the Database, consists of approximately 1797 entries or FEPs. The FEPs have been classified as Primary and Secondary FEPs and have been assigned to various PMRs. The assignments were based on the nature of the FEPs so that the analysis and resolution for screening decisions reside with the subject-matter experts in the relevant disciplines. The resolution of other than EBS FEPs is documented in AMRs prepared by the responsible PMR groups. Several relevant FEPs do not fit neatly into the existing PMR structure. Some FEPs were best assigned to the TSPA itself (i.e., system-level and criticality FEPs), rather than to its component models.

This AMR addresses 88 primary FEPs. 86 Primary FEPs were explicitly identified as EBS FEPs in the Database (CRWMS M&O 2000gg). After reviewing the database, it was determined that there were an additional 2 Primary FEPs that were relevant to the EBS (FEP numbers 2.1.08.14.00 and 2.2.01.04.00). These 88 FEPs represent the key features of the EBS, processes that result in degradation of these features, and processes that occur within the EBS that influence other aspects of the repository. The 88 Primary EBS FEPs addressed in this AMR are presented in Section 6.1. EBS screening is documented in Section 6.4. EBS process model screening considerations for selected FEPs are summarized in Attachment I.

A separate, independent EBS FEP identification of EBS FEPs process was developed to ensure the completeness of the FEPs in the Database. This effort identified 37 FEPs (including 5 common-cause failure events) relevant to the EBS. These FEPs, which are described in Section 6.2, are all shown to have corresponding primary FEPs in Section 6.3, and are implicitly considered during the screening of the set of 88 Primary FEPs.

On January 26, 2000, a design change was initiated to resolve certain thermal design issues. This design change will result in a greater ability of the waste packages to reject heat after closure of the repository, thereby maintaining the two thermal requirements. The first requirement is protection of the fuel cladding, and the second requires that a section of the rock pillar between drifts remain below the boiling temperature of water, providing a path for water drainage. This design change is directed in Technical Change Request: "Site Recommendation Design Baseline." TCR: T2000-0133 dated January 26, 2000 (CRWMS M&O 2000), and documented in part in the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 2000bb). This AMR originally considered a design with backfill. The current revision of this AMR focuses on the design without backfill, while retaining the backfill as an optional design feature.

1.2 FEPS IDENTIFICATION AND ANALYSIS OF DATABASE FEPS

This section describes the identification and analysis of EBS FEPs documented in the Yucca Mountain FEP Database. Section 6.1 describes an alternative, independent identification process that is specific to the YM EBS.

For the YMP TSPA, a scenario is defined as a subset of the set of all possible futures of the engineered barrier system that contains the futures resulting from a specific combination of FEPs. The first step of the scenario development process is the identification of FEPs potentially relevant to the performance of the Yucca Mountain repository. The most current list of FEPs is contained in the YMP FEPs Database (CRWMS M&O 2000gg). A comprehensive discussion of the origin of these FEPs, their organization, and their assignment to the various PMRs is provided in the documentation accompanying the Database (CRWMS M&O 2000gg). A brief summary of that discussion follows.

The initial set of FEPs was created for the Yucca Mountain TSPA by combining lists of FEPs previously identified as relevant to the Yucca Mountain Project (YMP) (e.g., *Total System Performance Assessment-1995: An Evaluation of the Potential Yucca Mountain Repository,* CRWMS M&O 1995a) with a draft FEPs list compiled by the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-Operation and Development (OECD) (SAM 1997). The

NEA list is maintained as an electronic FEPs Database and is the most comprehensive list available internationally. The list currently contains 1261 FEPs from Canadian, Swiss, and Swedish spent-fuel programs, intermediate and low-level waste programs of the U.K., and the U.S. Waste Isolation Pilot Plant (WIPP) program. An additional 292 FEPs have been identified from YMP literature and site studies, 82 FEPs have been identified during YMP project staff workshops, 9 FEPs have been identified by subject matter experts during preparation of AMRs for REV00 of the YMP FEPs Database (CRWMS M&O 2000gg), and 2 FEPs have been identified by the NRC during review. These FEPs are organized under 151 categories, based on NEA category headings, resulting in a total of 1797 entries. Consistent with the diverse backgrounds of the programs contributing FEPs lists, FEPs have been identified by a variety of methods, including expert judgement, informal elicitation, event tree analysis, stakeholder review, and regulatory stipulation. All potentially relevant FEPs have been included, regardless of origin. This approach has led to considerable redundancy in the FEPs list, because the same FEPs are frequently identified by multiple sources, but it also ensures that a comprehensive review of narrowly defined FEPs will be performed. The FEPs list (CRWMS M&O 2000gg) is considered open and will continue to grow as additional FEPs are identified.

Under the definition adopted for the Yucca Mountain TSPA, a scenario is defined as a subset of the set of all possible futures of the engineered barrier system that contains the futures resulting from a specific combination of FEPs. There is no uniquely correct level of detail at which to define scenarios or FEPs. Decisions regarding the appropriate level of resolution for the analysis are made based on consideration of the importance of the scenario in its effect on overall performance and the resolution desired in the results. The number and breadth of scenarios depend on the resolution at which the FEPs have been defined: coarsely defined FEPs result in fewer, broad scenarios, whereas narrowly defined FEPs result in many narrow scenarios. For efficiency, both FEPs and scenarios should be aggregated at the coarsest level at which a technically sound argument can be made that is adequate for the purposes of the analysis.

Consequently, each FEP has been identified as either a Primary or Secondary FEP. Primary FEPs are those FEPs for which the project proposes to develop detailed screening arguments. The classification and description of Primary FEPs strives to capture the essence of all the Secondary FEPs that map to the primary. For example, the Primary FEP "Physical and Chemical Properties of Backfill" can be used appropriately to resolve multiple and redundant Secondary FEPs that address various aspects of the backfill properties and their impact on groundwater flow and radionuclide transport at YMP. By working to the Primary FEP description, the subject matter experts assigned to the Primary FEP address all relevant Secondary FEPs, and arguments for Secondary FEPs can be rolled into the Primary FEP analysis. Secondary FEPs are either FEPs that are completely redundant or that can be aggregated into a single Primary FEP. The number of Secondary FEPs associated with each Primary FEP varies. In some cases, there are no Secondary FEPs. In other cases, there may be as many as three dozen Secondary FEPs. This is simply a function of how many different sources of input were received for the data base.

To perform the screening and analysis, the FEPs have been assigned based on the PMR structure so that the analysis, screening decision, and TSPA disposition reside with the subject matter experts in the relevant disciplines. The TSPA recognizes that FEPs have the potential to affect multiple facets of the project, may be relevant to more than one PMR, or may not fit neatly within the PMR structure. For example, many FEPs affect waste form (WF), waste package (WP), and the EBS. Rather than create multiple separate FEPs, the FEPs have been assigned, as applicable, to one or more process modeling groups, which are responsible for the AMRs.

At least two approaches have been used to resolve overlap and interface problems of multiple assigned FEPs. FEP owners from different process modeling groups may decide that only one PMR will address all aspects of the FEP, including those relevant to other PMRs. Alternatively, FEP owners may each address only those aspects of the FEP relevant to their area. In either case, the FEP AMR produced by each process modeling group lists the FEP and summarizes the screening result, citing the appropriate work in related AMRs as needed.

This AMR addresses the 88 FEPs that have been identified as Primary EBS FEPs from the FEPs database (CRWMS M&O 2000gg). In addition, 37 EBS FEPs have been identified independently from the Database (see Section 6.2). These are separately addressed to ensure the completeness of the FEPs database, related to the existing Primary FEPs from the database, and then implicitly considered in the screening discussion for those primary FEPs. In those cases where the FEP is relevant to other process modeling groups, only the relevance of the FEP to the EBS is discussed herein. Overlap with other process modeling groups occurs for the following areas; WF degradation (CRWMS M&O 2000q), WP degradation (CRWMS M&O 2000w), disruptive events evaluation (CRWMS M&O 2000s), the near-field environment (NFE) as defined by its thermal hydrology and coupled processes (CRWMS M&O 2000r), and the unsaturated zone (CRWMS M&O 2000u). It should be noted that in a few cases such a FEP has been designated as "excluded" from the TSPA relative to the EBS. It is important to note, however, that such a designation of "exclude" for the EBS does not mean that the FEP is necessarily "excluded" relative to another process modeling group.

1.3 FEPS SCREENING AND ANALYSIS PROCESS

As described in Section 1.2, the first step in the TSPA scenario development process was the identification of FEPs. The second step in the scenario development process includes the screening of each FEP. Each FEP is screened for inclusion or exclusion in the TSPA against three criteria, which are stated as regulatory requirements at NRC's proposed rule 10 CFR Part 63 (64 FR 8640), and in the U.S. Environmental Protection Agency's (EPA) proposed rule 40 CFR Part 197 (64 FR 46976). The screening criteria are discussed in more detail in Section 4.2 and are summarized here.

- Does the FEP have a probability of occurrence less than 10^{-4} in 10^4 years?
- Will the resulting expected annual dose be "significantly changed" or the results of the performance assessment be "changed significantly" by omission of the FEP? (Note: "significantly changed" and "changed significantly" are undefined terms in the DOE Interim Guidance and in the EPA's proposed regulations. These terms are inferred to mean that the lack of such "significant change" is equivalent to having no or negligible effect.)
- Is the FEP specifically ruled out by the guidance or proposed regulations, or contrary to the stated guidance or regulatory assumptions?

Probability-based screening arguments used in the FEPs screening process may be based on technical analysis of the past frequency of similar events (such as igneous and seismic events) or, in some cases, on expert elicitation. Probability arguments, in general, require including some information about the magnitude of the event in its definition. Probability arguments are also sensitive to the spatial and temporal scales at which FEPs are defined. For example, the definition of the probability of a seismic event depends on the magnitude of the event. Probability arguments are therefore made at reasonably coarse scales.

Consequence-based screening arguments can be established in a variety of ways. Various methods include TSPA sensitivity analyses, modeling studies outside of the TSPA, or reasoned arguments based on literature research. For example, consequences of many geomorphic processes such as erosion and sedimentation can be evaluated by considering bounding rates reported in geologic literature. More complicated processes, such as igneous activity, require detailed analyses conducted specifically for the Yucca Mountain Project. Low-consequence arguments are often made by demonstrating that a particular FEP has no effect on the distribution of an intermediate performance measure in the TSPA. For example, by demonstrating that including a particular WF has no effect on the concentrations of radionuclides transported from the repository in the aqueous phase, it is also demonstrated that including this waste form in the inventory would not compromise compliance with the performance objectives. Explicit modeling of the characteristics of this waste form could therefore be excluded from the TSPA.

The regulatory screening criteria contained in DOE's interim guidance (Dyer 1999) and in the proposed 40 CFR Part 197 (64 FR 46976) are relevant to many of the FEPs in the database. FEPs that are contrary to DOE's interim guidance, or specific proposed regulations, regulatory assumptions, or regulatory intent are excluded from further consideration. Examples include: the explicit exclusion of consideration of all but a stylized scenario to address treatment of human intrusion 10 CFR 63.113(d) (64 FR 8640), assumptions about the critical group to be considered in the dose assessment 10 CFR 63.115 (64 FR 8640), and the intent that the consideration of "the human intruders" be excluded from the human intrusion assessment (64 FR 8640, Section XI. Human Intrusion).

Using the type of arguments discussed above, each FEP identified as relevant to the EBS was reviewed against the three screening criteria. Those that were determined to meet one of the three criteria were designated as "excluded" from further consideration within the TSPA. Those that did not meet one of these criteria must, by definition, be "included." It should be noted that for the EBS-related FEPs in the database, none were screened out on the basis of the regulatory criteria identified above. Only probability and consequences-based arguments were used.

1.4 ORGANIZATION OF THE YM FEP DATABASE

The YM FEP Database (CRWMS M&O 2000gg) is an electronic database that was created by the TSPA Database team to assist project reviewers during the license application review process. Each FEP has been entered as a separate record in the Database. Fields within each record provide a unique identification number, a description of the FEP, the origin of the FEP, identification as a Primary or Secondary FEP, and mapping to related FEPs. Fields also provide summaries of the screening arguments with references to supporting documentation and AMRs, and, for all retained FEPs, statements of the disposition of the FEP within the TSPA modeling system. The AMRs, however, contain the detailed arguments and description of the disposition of the subject FEPs.

Alphanumeric identifiers (called the "NEA category") previously used have been retained in the Database for traceability purposes. Each FEP has also been assigned a unique YMP FEP Database number, based on the NEA categories. The Database number is the primary method for identifying FEPs, and consists of an eight-digit number of the form x.y.zz.pp.qq. The general structure of the Database is reflected in the first two digits (x.y) as shown below:

0.0. Assessment Basis

1.0. External Factors

- 1.1 Repository Issues
- 1.2 Geological Processes and Effects
- 1.3 Climatic Processes and Effects
- 1.4 Future Human Actions (Active)
- 1.5 Other

2.0. Disposal System - Environmental Factors

- 2.1 Wastes and Engineered Features
- 2.2 Geologic Environment
- 2.3 Surface Environment
- 2.4 Human Behavior

3.0. Disposal System - Radionuclide/Contaminant Factors

- 3.1 Contaminant Characteristics
- 3.2 Contaminant Release/Migration Factors
- 3.3 Exposure Factors

The first digit, x, represents the layer, and the second digit, y, represents the category. The next four digits (zz.pp) define a grouping structure for the FEPs, with zz designating the heading, and pp designating the Primary FEP number. The exact details of this grouping structure are not important to the evaluation, since each FEP will be evaluated regardless of the Database organization. Finally, the last two digits (qq) provide the Secondary FEP number (Primary FEPs are designated 00). Each heading has a Primary FEP associated with it, and may or may not have any Secondary FEPs. In those cases where Secondary FEPs do exist, the Primary FEP encompasses all the issues associated with the Secondary FEPs. The Secondary FEPs either provide additional detail concerning the primary, or are a restatement of the primary based on redundant input from a different source.

2. QUALITY ASSURANCE

The activities documented in this AMR were developed in accordance with the Technical Work Plan (CRWMS M&O 2000ll) and were determined to be quality affecting and subject to the requirements of the U.S. DOE Office of Civilian Radioactive Waste Management (OCRWM) *Quality Assurance Requirements and Description* (QARD) (DOE 2000). Accordingly, the modeling or analysis activities documented in this AMR have been conducted in accordance with the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) quality assurance program, using approved procedures identified in the Technical Work Plan (CRWMS M&O 2000ll).

More specifically, this AMR has been developed in accordance with procedure AP-3.10Q, *Analyses and Models*. Preparation of this analysis did not require the classification of items in accordance with QAP-2-3, *Classification of Permanent Items*. This activity is not a field activity. Therefore, an evaluation in accordance with NLP-2-0, *Determination of Importance Evaluations* was not required.

The initial list of 88 Primary EBS FEPs addressed in this AMR is a subset extracted from the *YMP FEP Database Rev. 00* (CRWMS M&O 2000gg). The 37 independently identified EBS FEPs (see Section 6.2) will also be addressed to determine if additional EBS Primary FEPs need to be included in the Database. The FEPs Database is a Level 3 Milestone document that is one of the Total System Performance Assessment - Site Recommendation (TSPA-SR) deliverables. The methods used to control the electronic management of this data as required by AP-SV.1Q, *Control of the Electronic Management of Information*, were accomplished in accordance with the controls specified in the Technical Work Plan (CRWMS M&O 2000ll). No other data was used in the development of this AMR.

3. COMPUTER SOFTWARE AND MODEL USAGE

This AMR uses no computational software or model. The AMR was developed using only commercially available software (Microsoft Word 97 and Powerpoint) for word processing and graphics, which is exempt from qualification requirements in accordance with AP-SI.1Q, *Software Management*. There were no additional applications (routines or macros) developed using this commercial software. The analyses and arguments presented herein are based on regulatory requirements, results of analyses presented and documented in other AMRs, or technical literature. It should be noted that the FEP database that is referred to in this AMR is a Microsoft Access 97 database, which is also commercially available software.

4. INPUTS

4.1 DATA AND PARAMETERS

The nature of the FEPs screening arguments and TSPA dispositions is such that cited data and values form the basis of reasoned argument, as opposed to inputs to computational analyses or models. The AMRs listed in Table 7 and referred to in Section 6.4 and Attachment 1 were used for information or reference only. The data cited in the FEPs screening arguments is largely non-critical, and conclusions will be formulated such that they will not be affected by the degrees of uncertainty accounted for in the TSPA.

In addition to the above input, the potential repository baseline design (CRWMS M&O 2000bb) was used as the reference design for the purpose of FEP identification and analysis. The design documented therein does consider the use of backfill material within the EBS. On

January 26, 2000, a design change was initiated to resolve certain thermal design issues. This design change will result in a greater ability of the waste packages to reject heat after closure of the repository, thereby maintaining the two thermal requirements. The first requirement is protection of the fuel cladding, and the second requires that a section of the rock pillar between drifts remain below the boiling temperature of water, providing a path for water drainage. This design change is described in the Monitored Geologic Repository Project Description Document (CRWMS M&O 2000bb). This AMR originally considered a design with backfill, and is now focused on the design without backfill.

4.2 CRITERIA

This AMR complies with the DOE interim guidance (Dyer 1999). Subparts of the interim guidance that apply to this analysis or modeling activity are those pertaining to the characterization of the Yucca Mountain site (Dyer 1999, Subpart B, Section 15). In particular, relevant parts of the guidance include the compilation of information regarding geology, hydrology, and geochemistry of the site (Dyer 1999, Subpart B, Section 21(c)(1)(ii)), and the definition of geologic, hydrologic, and geochemical parameters and conceptual models used in performance assessment (Dyer 1999, Subpart E, Section 114(a)).

Technical screening criteria are provided in DOE's interim guidance (Dyer 1999) and have also been identified by the NRC in the proposed 10 CFR Part 63 (64 FR 8640) and by the EPA in the proposed 40 CFR Part 197 (64 FR 46976). Both proposed regulations specifically allow the exclusion of FEPs from the TSPA if they are of low probability (less than one chance in 10,000 of occurring in 10,000 years) or if occurrence of the FEP can be shown to have no significant effect on expected annual dose. There is no quantified definition of "significant effect" in the guidance or proposed regulations. It is also possible that certain FEPs could be outside the scope of the regulations, specifically excluded by those regulations, or inconsistent with the assumptions contained in those regulations.

4.2.1 Low Probability

The probability criterion is explicitly stated by the NRC in the proposed 10 CFR §63.114 (d) (64 FR 8640):

> Consider only events that have at least one chance in 10,000 of occurring over 10,000 years.

The EPA provides essentially the same criterion in 40 CFR 197.40 (64 FR 46976):

> The DOE's performance assessments should not include consideration of processes or events that are estimated to have less than one chance in 10,000 of occurring within 10,000 years of disposal.

4.2.2 Low Consequence

Criteria for low consequence screening arguments are provided in DOE's interim guidance (Dyer 1999, Section 114(e) and (f)), which indicates that performance assessment shall:

(e) Provide the technical basis for either inclusion or exclusion of specific features, events, and processes of the geologic setting in the performance assessment. Specific features, events, and processes of the geologic setting must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.

(f) Provide the technical basis for either inclusion or exclusion of degradation, deterioration, or alteration processes of engineered barriers in the performance assessment, including those processes that would adversely affect the performance of natural barriers. Degradation, deterioration, or alteration processes of engineered barriers must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.

The EPA provides essentially the same criteria in 40 CFR 197.40 (64 FR 46976):

> ...with the NRC's approval, the DOE's performance assessment need not evaluate, in detail, the impacts resulting from any processes and events or sequences of processes and events with a higher chance of occurrence if the results of the performance assessment would not be changed significantly.

The terms "significantly changed" and "changed significantly" are undefined terms in the DOE interim guidance and in the EPA's proposed regulations. These terms are inferred for FEPs screening purposes to mean that the lack of such "significant change" is equivalent to having no or negligible effect. Because the relevant performance measures differ for different FEPs (e.g., effects on performance can be measured in terms of changes in concentrations, flow rates, travel times, and other measures, as well as overall expected annual dose), there is no single quantitative test of "significance."

4.2.3 Regulatory Exclusion

Both DOE's interim guidance (Dyer 1999) and EPA's proposed regulations specify assumptions (which in effect serve as criteria) pertinent to screening many of the EBS FEPs. Particularly germane are explicit assumptions regarding the reference biosphere 10 CFR 63.115 (64 FR 8640), and less so are assumptions regarding the location and use of groundwater by the critical group used for calculation of exposure doses.

The assumptions pertaining to the characteristics of the reference biosphere are presented in DOE's interim guidance (Dyer 1999, Section 115(a)(1,4)). The specified characteristics pertinent to the EBS FEPs are that:

(1) Features, events, and processes ...shall be consistent with present knowledge of the conditions in the region surrounding the Yucca Mountain site.

(4) Evolution of the geologic setting shall be consistent with present knowledge of natural processes.

The EPA has specified a similar assumption in proposed 40 CFR 197.15 (64 FR 46976). This assumption is stated as:

> ...DOE must vary factors related to the geology, hydrology, and climate based on environmentally protective but reasonable scientific predictions of the changes that could affect the Yucca Mountain disposal system over the next 10,000 years.

FEPs that are inconsistent with such regulatory assumptions would be excluded on the basis of regulatory exclusion.

4.2.4 Implicit Criteria

In addition to these enumerated formal criteria, there is the implicit criterion that the FEP originating in the International Database must be relevant to Yucca Mountain. Many entries in the International Database describe features, events or processes that are not physically possible at Yucca Mountain for geologic, hydrologic or design reasons. While these FEPs are excluded on the basis of low probability, they are also identified with a remark indicating that they are not credible.

In addition, certain FEPs, having favorable consequences, are excluded from consideration on the basis of low consequence. Their quantification may require data and/or models that are not available, or they may contribute a minor impact, which is hard to quantify. The argument is that to exclude such FEPs is a conservative practice that overestimates consequences. While such FEPs are excluded at this time, they may be included in the future.

4.3 CODES AND STANDARDS

This AMR was prepared to comply with the DOE interim guidance (Dyer 1999), which directs the use of specified Subparts/Sections of the proposed NRC high-level waste rule, 10 CFR Part 63 (64 FR 8640). Subpart E, Section 114 (Requirements for Performance Assessment) pertains to this work.

5. ASSUMPTIONS

5.1 GENERAL ASSUMPTIONS

There are two general assumptions used in the screening of the EBS FEPs.

5.1.1 Future Geologic Setting

As directed by DOE's interim guidance (Dyer 1999, Section 114(1)), the TSPA assumes that future geologic settings will be within the range of conditions that are consistent with present knowledge of natural processes.

This assumption is particularly germane to EBS FEPs, since the FEPs are screened based on known processes or phenomena that could potentially affect future states of the system. Discernible impacts from past events on the geologic setting are inherently reflected in the present knowledge of natural processes that form the basis of the TSPA. If the subject FEP phenomena do not have a documented past occurrence within the geologic time scale of concern and/or within the study area, or if past events are of an insignificant consequence, then it is by definition a low probability or low consequence event and can be excluded from consideration.

5.1.2 Repository Closure

The TSPA is based on an assumption that the repository will be constructed, operated, and closed according to regulatory requirements in effect at the time.

This assumption is particularly germane to FEPs involving off-normal events during the construction phase of the repository or deviations from the as-designed repository configuration. By definition, such events and/or design deviations will not be explicitly considered in the TSPA.

These two assumptions are justified based on the conditions specified in DOE's interim guidance (Dyer 1999), which require special and periodic reporting of (1) progress of construction, (2) data not within predicted limits on which the facility design is based, and (3) any deficiency, that if uncorrected, could adversely affect safety. Additionally, restrictions on subsequent changes to the features or procedures will be a condition of construction authorization. Furthermore, the existing regulations specified in 10 CFR 63 Subpart F (Dyer 1999) require that a performance confirmation program be instituted. The focus of the program is to confirm the geotechnical design parameters and to ensure that appropriate action is taken to inform the NRC of changes needed to accommodate actual field conditions. It also includes provisions for design testing and monitoring of testing of waste packages to verify in-situ performance of the waste package design. The requirement is for these activities to be conducted in a manner that does not adversely affect the ability of the geologic and engineered elements of the geologic repository to meet the performance objectives. Additionally, all of these activities are subject to the quality assurance requirements specified in 10 CFR 63 Subpart G (Dyer 1999). Regardless of this assumption, the TSPA includes the possibility that engineered systems may not perform optimally for the full 10,000 years. For example, the premature failure of some waste packages is included in the TSPA through the probabilistic treatment of waste package degradation.

5.2 FEP-SPECIFIC ASSUMPTIONS

This section lists the EBS-specific assumptions used in Section 6. All of the assumptions were used as reference or logical analysis assumptions to facilitate the identification and analysis of FEPs and degradation scenarios. None of the assumptions is a requirement that needs to be substantiated and, hence, none carries a TBV. It is particularly noted that, conceptually, all of the events and processes identified are potential scenarios, and as such, are assumed to occur for the purpose of analysis. It is also noted that the current repository baseline design (CRWMS M&O 2000bb) is used as a point of departure for FEP identification, but the latter is not restricted by the configuration or design requirements specified in that baseline. Examples of FEPs that go "beyond" the baseline are the development of gaps between drip shield segments due to a seismic event.

5.2.1 Engineered Barrier System Description

The EBS is assumed to extend as far into the rock as the reach of the ground support system (approximately 5 m if rock bolts are used). Thus, chemical processes involving such rock bolts and the surrounding cement are considered, as is degradation of the drift wall in this region. However, the determination of seepage flow into the tunnel, including the impact of geophysical changes in this region of the rock, is an NFE issue and is not considered as part of this EBS discussion. All flow into the tunnel is assumed to be provided as a boundary condition by the NFE analysis.

5.2.2 Reference Repository Design

The Enhanced Design Alternative II, as described in the baseline design (CRWMS M&O 2000bb), is used as the reference design for FEP identification. Additional information is provided in supplemental documentation on subsurface facilities (CRWMS M&O 2000z) and ground control systems (CRWMS M&O 2000aa). Key features of this design include the waste package sitting atop a pedestal and invert and a drip shield to minimize water contact with the waste packages. No backfill is considered in the current design, although the potential use of backfill can be re-evaluated if that option is selected in the future. A 50 year preclosure ventilation period (CRWMS M&O 2000bb) ensures that maximum waste package temperatures are kept below allowable limits. However, departures from the baseline due to the potential occurrence of FEPs are also addressed.

5.2.3 Degradation

Evolution of the repository over time is assumed to result in degradation in performance; any potential improvements in performance as a result of such evolution are conservatively ignored..

- As the potential repository and Yucca Mountain evolve, the properties of EBS components such as the ground support and the drip shield, which are subjected to "processes," depart from their original design characteristics. By assumption, it is presumed that any such departure degrades the function of the component, and design lifetimes and safety factors are selected on the basis of that premise.

- The design philosophy currently assumes no credit for favorable alterations to the repository system (e.g., encasement of WPs in calcium carbonate precipitated from incoming water).

5.2.4 Degradation During Preclosure Period

Degradation that occurs during the preclosure period would be detected and "fixed." Thus, the FEPs identified are mostly those that occur during the postclosure period.

5.2.5 Process Starting Point

The starting point of most EBS processes is assumed to be the entry of water into the emplacement drift. It is with the introduction of water that key degradation processes such as corrosion start to occur. However, there are certain processes that are independent of water ingress that must also be considered. These include, for example, rock fall and the deposition of dust on the waste packages and drip shields. Rock fall may occur at any time after repository closure and could represent a mechanism for drip shield damage. Dust deposited on the drip shields and waste packages prior to repository closure would serve as loci for surface wetting when the relative humidity increases, but prior to liquid water entry.

All data associated with water entry into the emplacement drift, including timing, rate, temperature, chemistry, etc., are assumed to be developed in the unsaturated zone and near field environment PMRs (CRWMS M&O 2000nn, 2000pp).

6. ANALYSIS/MODEL

In this section, EBS FEPs are identified and evaluated to determine whether the FEPs need to be included in, or can be excluded from the TSPA scenarios, based on the criteria delineated in Section 4.2.

The set of FEPs identified and evaluated in this section is developed from two independent sources, from the International FEPs Database and from an independent examination of the EBS. The FEPs provided in the International Database relevant to the EBS are an assemblage from diverse waste management projects, all in environments different from Yucca Mountain. Those FEPs developed independently for Yucca Mountain, are focused strictly on the EBS design and associated processes at Yucca Mountain. The two sets overlap where similar physical processes and design elements are identified and differ where site-specific processes and design enter.

The 88 EBS FEPs that are documented in Revision 00 of the YM FEP Database (CRWMS M&O 2000gg) are presented in Section 6.1. A comprehensive development of EBS FEPs, independent from the database, is then described in Section 6.2. The relationships between these independently developed FEPs and those in the Database are presented in Section 6.3. The purpose for this correlation is to demonstrate the completeness of the FEPs that are in the Database, and in some cases enhance the description of a Database FEP. Finally, in Section 6.4, the screening arguments for the FEPs are presented, relative to their inclusion in or exclusion from TSPA.

For importance purposes as discussed in *Managing Technical Product Inputs*, AP-3.15Q, this analysis is classified as "Level 3" since it does not provide estimates of any of the Factors or Potentially Disruptive Events listed in the Screening Criteria for Grading of Data attachments in AP-3.15Q.

6.1 EBS FEPS FROM THE YM FEP DATABASE

The FEPs identified in the YM FEP Database (CRWMS M&O 2000gg) that were determined to be relevant to the EBS are summarized in Table 1. Note that FEP 2.1.08.04.00 was modified relative to Revision 00 of the database. In the database, this FEP was listed as "Condensation Forms on Back of Drifts." It was broadened to "Cold Traps" in this document, with the "Condensation on Back of Drifts" becoming a secondary FEP entry.

6.2 INDEPENDENT IDENTIFICATION OF EBS FEPS

The process of identifying EBS FEPs consists of several interdependent steps: (1) identification of a FEPs "Basis," a collection of EBS FEPs, as well as consequences of processes that need to be accounted for; (2) construction of a number of figures that detail the EBS and how the EBS interacts with the flow system; (3) development of a logic diagram to organize and connect the components of the EBS figures and add missing elements; and (4) development of a fault tree focused on "common cause" failures to systematically identify those modes. Steps (1) through (4) are described below. The identification approach described above is not dependent on the FEPs that have so far been identified in the Database (Section 6.1). The purpose is to ensure that all FEPs that have their origin in other sources are addressed.

In order to identify FEPs germane to degradation of the EBS design and performance, it is necessary to define the terms degradation and common cause degradation.

Degradation

As the potential repository and Yucca Mountain evolve, the properties of EBS components such as ground support, backfill, and drip shields, which are subjected to "processes," depart from their original design characteristics. By assumption, it is presumed that any such departure degrades the function of the component, and design lifetimes and safety factors are selected on the basis of that premise. The design philosophy currently assumes no credit for favorable alterations to the repository system (e.g., encasement of WPs in calcium carbonate precipitated from incoming water). Therefore, degradation is defined as occurring for all components.

Common Cause Degradation

The potential repository is designed so that there is defense-in-depth, that is, a number of components can individually fail to perform without compromising repository performance. However, it is sometimes possible to identify failure modes in engineered structures that compromise all of the critical components simultaneously, thus producing "common cause failures." To allow for this possibility in the EBS, in addition to examining the degradation of individual components, it is necessary to search for single events or processes that have the potential for causing multiple-component degradations and, ultimately, increasing the possible dose release.

Usually, "common cause failure" describes the failure of several critical, redundant components due to a single event that simultaneously affects all critical components. A detailed discussion of "common cause" and "common mode" failures and their implications can be found in *Reliability and Risk Analysis – Methods and Nuclear Power Applications* (McCormick 1981, p. 88f) or equivalent text. In this analysis, "common cause degradation," or "common cause" will be used to describe: (1) the degradation or failure of several critical components due to a single event; (2) processes initiated by a single event; or (3) a single process that compromises several critical components and accelerates the potential release rate. An example is movement of a fault that passes through the potential repository. This event could (1) suddenly cause a local ground support collapse that damages a WP and exposes it to water contact, (2) provide a pathway for water influx that would accelerate corrosion and mobilization, and (3) provide an exit for possible radionuclide transport.

6.2.1 Basis for EBS FEPs Identification

To develop a basis for EBS FEPs, a number of process categories (issues, concerns, and advice from the principal investigators) relevant to degradation of the EBS have been considered. The processes in each category influence the degradation of the EBS components and could induce their eventual failure. Some of these are FEPs in their own right, while others are the consequences of processes involving more fundamental FEPs or are summaries of FEPs. Table 2 lists the process categories considered, and identifies significant and potentially degrading effects in each category.

The potential repository baseline design (CRWMS M&O 2000bb) was used as the reference repository design for identifying FEPs and degradation scenarios. Numerous design options are possible. Development of EBS FEPs requires a specific design be chosen. Here the design option is for "open drifts" (No backfill in the emplacement drifts above and around the drip shield). The "Backfill" option is carried along in the discussion in order to illustrate how a specific design option alters the process and to provide a connection with an earlier version of this document in which "Backfill" was considered a preferred option. The evaluation and screening of FEPs in Section 6.4 exclude backfill-related FEPs as currently not applicable.

The "Basis" listed in Table 2 is effectively a bookmark, or reference consideration, that reminds the analysts of issues, concerns, and advice perceived to be important by the principal investigators of FEPs in other areas and which need to be accounted for as the FEPs are developed for the EBS.

6.2.2 Conceptual Figures

To clarify the importance and context of the FEPs, and to illustrate some of the principal FEPs, several figures have been constructed to illustrate the potential degradation of principal elements of the EBS. It is noted that Figures 1 through 6 represent hypothetical, but possible, degradation scenarios considered for the purpose of analysis rather than design. In addition, certain expected and important physical behaviors, namely floor buckling and stress-adjustment fracturing, are also shown. Such behaviors and their analyses are discussed in publications such as *Rock Mechanics for Underground Mining* (Brady and Brown 1993), *Fundamentals of Rock Mechanics* (Jaeger and Cook 1979), and articles such as "Impacts of Seismic Activity on Long-Term Repository Performance at Yucca Mountain" (Gauthier et al. 1996, pages 159 - 168). The ground support system has been omitted from the figures for clarity. For the backfill design option an alternative set of illustrations, Figures 1A through 6A, was developed. Unless noted otherwise, the discussion of Figures 1 through 6 below applies to both sets of figures.

Figure 1 presents the principal elements of the EBS and a conceptualization of floor buckling in the form of a downward displacement. The "sag" is accompanied by the relative movement of two overlapping segments of the drip shield. This relative movement results in potential gaps between drip shield segments, allowing flow of water (and backfill, if used, see Figure 1A) to the inside of the drip shield. If the drip shield was diverting water from either of the displaced segments at the time, that water is likely to be focused into the invert at the location of the displacement, as suggested in the figure detail. Figure 1 also shows the residual condensate zones that could form due to cooling in the postclosure period. It shows rockfall atop the drip shield (or atop the backfill, if used), drift alteration, and a possible water flow area from the drift crown down a drift wall to the bottom of the invert. Fractures associated with stress-adjustment (thermo-mechanical and mechanical) are represented as a few fractures that are radially and concentrically distributed around the drift.

Figure 2 presents the same principal elements as in Figure 1, but shows the floor buckling in the form of a local rise of the floor. The detail of the overlapping drip shield segments provides a schematic representation of the associated flow of water, if available, (and backfill, if used, see Figure 2A) to the inside of the drip shield.

In Figure 3, two additional cross-sectional views, A and B, emphasize different details of the flow. Detail A shows flow from the drift wall down the drip shield (through the backfill, if used see Figure 3A) to the invert, condensate under the drip shield, and fracture drainage. Drift wall deformation is shown because the ground support system is expected to fail when the temperature has decreased sufficiently to create the condensate flow. Detail B shows flow over the drip shield and the invert, condensate under the drip shield, and fracture drainage. (If backfill is used, see Figure 3A, the discontinuous, locally saturated flow along the path is fed by fluid arriving at the saturated sites from flow through the backfill, perpendicular (in three-dimension) to the cross-section).

Possible effects of rockfall on the displacement of the drip shield are shown in cross-section in Figures 4 and 5. Here, rock falling on the drip shield distorts the drip shield (Figure 4) and displaces the drip shield (Figure 5) so that it contacts the WP and a rail section. As a result, rapid contact corrosion of the affected drip shield, the rail, and the WP would be expected. (Backfill, if used, see Figures 4A and 5A, is assumed to mitigate these effects by limiting the distortion of the drip shileld). Figures 6 and 6A (for the case where backfill is included) show the rock matrix and fractures around the emplacement drift cross section, as media for seepage inflow and drainage.

Figures 1 through 6 provide conceptual illustrations of most of the important EBS FEPs. Table 3 lists the FEPs illustrated and the corresponding figure numbers. Most of the EBS FEPs identified in this AMR can be developed from the above list and the figures by considering aspects and details of design, water chemistry, heat and corrosion mechanisms, etc. The remainder can be traced to the "Basis" of Table 2.

6.2.3 Logic Diagram

Integration of the FEPs, to provide context to their occurrence, is developed in the form of a logic diagram. The components used are typically of a summary or top-level nature and are intended to cover the key elements of water movement without providing overwhelming details of important supporting processes (e.g., various chemical interactions). Figures 1 through 6 provide a visual context for some components of the EBS and how they might function. The tree provides an operational context to ensure that all of the processes affecting the physical components in the EBS are addressed.

6.2.3.1 Context

The EBS FEPs, with the exception of three categories (ventilation, seals, and igneous activities; see Section 6.2.4), can be organized into a "context" of occurrence. This context assists in the elucidation and analysis of their importance in the degradation of the EBS. Context allows the investigator some perspective on which of the elements (i.e., FEPs) are controlling, which are developed (i.e., consequences), and which are of secondary importance.

This analysis includes the drip shield (and backfill, if used), which would be installed just prior to closure of the potential repository, and, therefore, applies to the long-term degradation of the EBS after closure. It is presumed that degradation that occurs during the preclosure period would be detected during preclosure inspection and remedied before closure.

The starting point of the EBS processes is assumed to be the entry of water into the emplacement drift. Water data, including timing, rate, temperature, chemistry, etc., are assumed to be developed in the unsaturated zone and near field environment PMRs. The flow in the drift evolves under the influence of the changing thermal output from the WPs.

6.2.3.2 Water Availability Conditions

Three conditions concerning the availability of water (contact water, mobilization water, and exit water) control the EBS FEPs and degradation modes.

6.2.3.2.1 Contact Water

First, there must be sufficient water available to reach the WP and to affect a breach of the WP by some corrosion mechanism. The water can be available as liquid or vapor, and corrosion can be by any number of mechanisms dependent on temperature, water chemistry, and water phase. While corrosion in the absence of water vapor (i.e., at low relative humidity) is also possible, it's rate is low compared to that under humid conditions (CRWMS M&O 2000w).

For this first condition, two different sources of water (infiltrate and condensate) and three different flow types (streaming flow, drip, and Philip's drip) are identified. **Infiltrate water** is defined as water that has entered at the surface and infiltrated through the rock to reach the repository. **Condensate water**, described here as the component "Return Flow," is defined as water that has been transported as vapor and has condensed in the rock, in the drift, or on the drip shield. The distinction is made on the grounds that the expected volumetric contributions, and their timing and chemistry, may be sufficiently different to be significant to degradation models (i.e., corrosion of the WPs). **Streaming flow** is a continuous flow of fluid, and **drip** is its intermittent or interrupted state. Drip is the currently expected condition, if it occurs at all. **Philip's drip** is a consequence of a drift of certain dimensions and shape intercepting a homogeneous, isotropic phreatic zone in such a way that it produces saturated conditions at the crown of the drift. This third flow type is esoteric, has been derived analytically, and is not currently supported experimentally nor expected to compete in volume with drip from infiltrate or condensate (Philip et al. 1989).

6.2.3.2.2 Mobilization Water

Second, there must be sufficient liquid water available to mobilize contaminants from the breached WP and move them through the invert. A WP failure (breach) by itself does not assure advective mobilization for some mechanisms of corrosion; vapor corrosion or microbial corrosion could have provided the breach. Waste temperature becomes an important constraint on the volume of water required to mobilize contaminants if the waste temperature would otherwise be above the vaporization temperature of water.

For this second condition, sufficient fluid must arrive at the breached WP to mobilize contaminants and move them through the invert. If the drip shield is intact, then the water source for liquid water moving through the breached WP must be limited to either condensation on the interior surface of the drip shield, or a rise of liquid in the invert sufficient to reach the breached WP. If the drip shield is not intact (e.g., due to physical displacement, gap, or corrosion), then water entering the drift could flow to the WP directly without being diverted by the drip shield. When ordering these possibilities independently on a volumetric basis, one might expect, first, a compromised drip shield, then, a rise of water level in the invert, and, last, condensation on the interior of the drip shield.

6.2.3.2.3 Exit Water

Third, there must be an exit from the EBS, either through the drift wall or the drift floor. The exit could be through fractures associated with thermo-mechanical effects and the existing fracture networks, or it could be matrix flow through the host rock. The functioning of the exit, which affects the residence time of mobilized contaminants in the EBS, also influences the mode by which the exit water takes contaminants away from the EBS.

For this third condition, exit from the EBS is defined as the escape of contaminants from the EBS. If fracture flow provides the primary path from the drift, fractures must be open and hydraulically active. Plugging, by fines or by mineralogical alterations (in a hot, wet environment) becomes a performance factor as does fracture closure by thermo-mechanical effects during the thermal period and the formation of new fracture sets as the repository cools. If matrix flow provides the primary path of escape from the EBS, then ponding, if any, and the residence time of contaminants in the drift become performance factors.

6.2.3.3 FEP Tree (Logic Diagram)

The above conditions, the factors and effects bases (Table 2) and the perspective provided in Figures 1 through 6 (Table 3), are expressed in the construction of the FEP logic tree, herein referred to as the "tree," shown in Figure 7. This figure is presented in totality and then as (magnified) segments (Figures 7a through 7f) for clarity. In this figure, the root event is assumed to be the arrival of water at the EBS. The process ends when the water exits the EBS. For the backfill design option an alternative set of illustrations, Figures 7A and 7Aa through 7Af, was developed. The discussion of Figure 7 below applies to both sets of figures.

The tree in Figure 7 was constructed to track water flow, and is based on flow to the drift occurring from two different sources: infiltrate and condensate ("Return Flow"). Only the Return Flow (condensate) branch is expanded, though the other branch (infiltrate) can be expanded similarly. These two possible sources are distinguished because different flow rates, volumes, water chemistries, temperatures, times of arrival, and locations are expected to be determined by their occurrence. All of these factors are considered important to modeling WP breach and contaminant mobilization.

The tree recognizes three flow types: drip, streaming flow, and Philip's drip. The last is included only for completeness, and is otherwise disregarded as being included in drip. Drip and streaming flow are only volumetrically different and are separated to recognize that flow may be distributed or may be well focused. Each intersection of the tree "branches" is an "OR" gate (any branch is possible); comments and FEPs are included in ovals where they may apply.

6.2.4 Features, Events, and Processes Set

A set of EBS FEPs has been identified, based on: (1) the baseline design of the potential repository (Wilkins and Heath 1999 and CRWMS M&O 2000bb), (2) the EBS FEPs basis in Table 2, (3) the conceptual figures (Figures 1 through 6), (4) the context described in Section 6.2.3.1, (5) the water availability conditions in Section 6.2.3.2, and (6) the logic diagram as developed in Section 6.2.3.3. This FEP set is identified in Table 4. The FEPs are numbered using the "ebs" symbol to distinguish them from Database FEPs.

Three potential FEPs implied by the "basis" in Table 2 are not listed in Table 4, nor are they addressed in the "context" discussion in Section 6.2.3.1. Rather, they are discussed in the next three paragraphs.

Ventilation, or the forced circulation of air through the drifts, is expected to continue until closure. This movement of air is expected to remove heat and moisture from the rock surrounding the drifts and therefore sets the initial conditions for the functioning of the EBS. Forced ventilation will cease after closure and is not part of the considerations for long-term behavior of the EBS. Therefore, no EBS FEPs for long-term releases are identified as resulting from ventilation. Ventilation as a design feature is discussed in more detail in the *ANSYS Thermal Calculations in Support of Waste Quality, Mix, and Throughput Study* (CRWMS M&O 1999) and is listed among the Database FEPs in Table 1.

Seals for plugging the openings produced during excavation and drilling operations are expected to be constructed to control the movement of water. No specific sealing requirements have been identified for the EBS; however, it is expected that seals would be emplaced in the ramps, ventilation shafts, and boreholes in the near field and away from the EBS. No seal-related FEPs have been identified for the EBS. Seals are considered to be design features, and are discussed in more detail in the *Repository Seals Requirements Study* (CRWMS M&O 1997).

Igneous activity refers to the interaction of an ascending magma dike and the repository drifts, and includes the possible formation of a vent and an associated contaminated cinder cone with an ash plume. The occurrence of the event and its consequences appear to be secondary to the EBS design. This topic and the FEPs it engenders are left to the PMR addressing volcanism (CRWMS M&O 2000mm) and are not considered here. Igneous activity is also discussed in more detail in *Scenarios Constructed for Basaltic Igneous Activity at Yucca Mountain and Vicinity* (Barr et al. 1993). Section 6.2.5 identify igneous event as a common-cause FEP, as shown in Tables 4 and 5.

6.2.5 Common Cause Degradation

To cause a common cause degradation, an event or process must occur that compromises the function of several key components as a direct result of an event or process that has the potential of affecting the release of contaminants from the EBS. The common cause degradation of the EBS can be "local" (i.e., affecting only a few adjacent or distributed WPs) or "nonlocal" (i.e., affecting a large part of or all of the repository).

As an example, consider the failure of the ground support system due to one or more of the following events or processes: (vibratory ground motion) seismic event, fault movement in the potential repository, thermo-mechanical movement in a shear zone, thermo-mechanical response producing floor buckling (and drift movement), corrosion of ground support (e.g., bolted steel sets), thermal-hydrologic-mechanical-chemical alteration of the Topopah Spring basal vitrophyre (propagating to the drifts as floor heave), and igneous event.

Such a ground support failure may result in events or processes with possible cascading effects that could displace the drip shield (and the backfill, if used), and directly damage the WP and its support, including the invert. Damage to the WP, which does not penetrate the WP but which accelerates corrosion, should also be considered as a common cause degradation, with delay. Advective release of contaminants, however, cannot occur unless the event or process causing failure of the ground support also includes sufficient water flow to assure the mobilization of contaminants from the WPs.

There are subsets of events and processes that affect part of the EBS components, which might also be considered as common cause degradations. An example is a (vibratory ground motion) seismic event that propagates down drifts causing relative movement of WPs and the drip shield (and backfill, if used) leading to contact corrosion, and for which there is incidental failure of the ground support.

A primitive fault tree for common cause degradation has been constructed in Figure 8 to aid in identifying the components associated with common cause degradation (see ovals in Figure 8). If a common cause exists, then it is expected to appear as a basic event occurring on every (or almost every) branch. This fault tree starts from the top with the release "fault" and progressively asks about changes that must occur to reach a "basic" initiating event. Branches are connected by "AND" gates, which require all branches immediately below the gate to occur in order to apply, or "OR" gates, which require any branch below the gate to occur.

Three requirements are identified in the tree as principal branches: (1) there must be enhanced water flow to the WPs, (2) there must be waste mobilization, and (3) there must be enhanced drainage to transport contaminants away. It is an implicit assumption that whatever the common caue, locally increased water flow to the drift will occur. Such a local increase of water flow means a local decrease elsewhere, as constrained by the water budget. As the fault tree is currently expanded, one branch, "water-mobilized contaminants," occurs for all releases. How this might be affected by local increases in water flow into the potential repository is ignored because it would require details of the water chemistry that are irrelevant to that point of the tree. This branch is connected by an "AND" gate to "Penetrated WPs," which is a requirement for any mobilization.

This construction of the fault tree (in Figure 8) shows that three basic events are shared for each of the principal branches. These are "Thermo-Mechanical Stress Alteration," "Thermal-Mechanical-Chemical-Hydrologic coupled processes" related to the Topapah Spring basal vitrophyre layer, and "Seismic Event." The last occurs in two forms, "local" and "nonlocal," to distinguish faulting that intercepts a drift from the effects of ground motion caused by the seismic event. Figure 8 identifies several common cause degradations for further evaluation in a TSPA context.

Table 5 summarizes the common cause events or processes affecting the EBS. Four are based on Figure 8, and igneous event types which are analyzed in the Disruptive Events PMR (CRWMS M&O, 2000mm). In general, common cause analysis requires the assessment of combined effects of FEPs that are typically analyzed within more than one discipline. The common causes in Table 5 are identified as input for assessment in a total system context. It is noted that these common cause events are also identified as ebs33 through ebs37 in Table 4, for correlation with Database FEPs in Section 6.3.

6.3 CORRELATION OF INDEPENDENT AND DATABASE FEPS

Table 6 relates the 37 ebs FEPs identified in Table 4 to the Database FEPs identified in Table 1. Because the 37 ebs FEPs were developed independently from the Database, there is considerable overlap between the two sets of FEPs. Many of the ebs FEPs restate ones that are already in the Database, and thus can be considered to be Primary or Secondary FEPs. Only two ebs FEPs could not be matched with Primary Database FEPs (based on an initial draft of the database). In these cases, the ebs FEPs (ebs23, ebs27) resulted in new input to the Database (2.1.08.13.00 and 2.1.08.12.00, respectively). This is reflected in Revision 00 of the database, which forms the basis for this assessment (CRWMS M&O 2000gg). Thus this AMR revision does not identify any "new primary" FEPs beyond those identified in Revision 00 of the Database (CRWMS M&O, 2000gg).

6.4 EBS FEPS SCREENING

The method used for this analysis is a combination of qualitative and quantitative screening of FEPs. The analyses are based on the criteria provided in the DOE's interim guidance (Dyer 1999) and by the EPA in the proposed 40 CFR Part 197 (64 FR 46976). These criteria are used to determine whether each FEP should be included in the TSPA (see Sections 1.3 and 4.2).

Screening Process

For FEPs that are excluded based on specific regulatory requirements (e.g., requirements regarding the location and composition of the critical group), the screening argument includes the regulatory reference and a short discussion of the applicability of the standard (no EBS FEPs are excluded on this basis).

For FEPs that are excluded from the TSPA based on DOE's interim guidance or EPA criteria, the screening argument includes the basis of the exclusion (low probability or low consequence) and provides a short summary of the screening argument. As appropriate, screening arguments cite work done outside this activity, such as in other AMRs.

For FEPs that are included in the TSPA, the TSPA Disposition includes a reference to the AMR that describes how the FEP has been incorporated in the process models and/or the TSPA abstraction.

To ensure clear documentation of the treatment of potentially relevant future states of the system in the Yucca Mountain License Application, the DOE has chosen to adopt a scenario development process based on the methodology developed by Cranwell et al. (1990) for the NRC. The approach is fundamentally the same as that used in many performance assessments. The approach has also been used by the DOE for the Waste Isolation Pilot Plant (WIPP) (DOE 1996), by the NEA, and by other radioactive waste programs internationally (e.g., Skagius and Wingefors 1992). Regardless of the "scenario" method chosen for the performance assessment, the initial steps in the process involve development of a FEPs list and screening of the FEPs list for inclusion or exclusion.

The approach used to identify, analyze, and screen the FEPs (as described in Sections 1.2 and 1.3) was also considered. Alternative classification of FEPs as Primary or Secondary is possible in an almost infinite range of combinations. Classification into Primary and Secondary FEPs is based primarily on redundancy and on subject matter. Subsequent assignment and analysis by knowledgeable subject matter experts for evaluation appeared to be the most efficient methodology for ensuring a comprehensive assessment of FEPs as they relate to the TSPA. Alternative classifications and assignments of the FEPs are entirely possible, but would still be based on subjective judgement. Alternative approaches for determining probabilities and consequences used as a basis for screening are discussed in Section 6.2 under the individual FEP analysis.

In practice, regulatory-type criteria were examined first, and then either probabilities or consequences were examined. FEPs that are retained on one criterion are also considered against the others. Consequently, the application of the analyst's judgement regarding the order in which to apply the criteria does not affect the final decision. Allowing the analyst to choose the most appropriate order to apply the criteria prevents needless work, such as developing quantitative probability arguments for low consequence events or complex consequence models for low probability events. For example, there is no need to develop detailed models of the response of the repository to faults shearing a WP, if it can be shown that this event has a probability below the criteria threshold.

Regardless of the specific approach chosen to perform the screening, the screening process is in essence a comparison of the FEP against the criteria specified in Section 4.2. Consequently, the outcome of the screening is independent of the particular methodology or assignments selected to perform the screening.

Alternative interpretations of data as they pertain directly to the FEPs screening are provided in the Analysis and Discussion section for each FEP, as discussed below. The FEPs screening decisions may also rely on the results of analyses performed and documented as separate activities. Alternate approaches related to separate activities and analyses are addressed in the AMRs for those analyses and are not discussed in this AMR.

Each of the 88 primary FEPs from the Database (no new primary FEPs taken from the ebs FEPs list were identified as addressed in Section 6.3) is discussed in the sections that follow. For the primary FEPs, the section title for each discussion provides the FEP name as incorporated in the FEPs Database (CRWMS M&O 2000gg), as well as the Yucca Mountain FEP number that has been assigned. The FEP description is also taken directly from the Database, with the exception that in several cases additional text has been added to reference applicable secondary FEPs relevant to the EBS discussion.

In addition, for each of the primary FEPs, the associated secondary FEPs were explicitly addressed to ensure that they were adequately encompassed by the Primary FEP description and screening result. Because the FEPs database retained all inputs from the various sources used to populate the database, many of the secondary FEPs are either:

- Completely redundant with another FEP and/or the associated primary FEP (in which case it is identified as redundant, but retained in the FEP list for completeness),
- Not relevant to Yucca Mountain because they deal explicitly with a design feature for a different repository, or
- Undefined because no information is provided other than a title.

The discussion for all secondaries will typically be very brief. Redundant secondary FEPs are simply identified as such. Secondary FEPs that pertain explicitly to design or site features not relevant to Yucca Mountain, are explicitly identified. Secondary FEPs with no additional descriptive information in the database are identified as such. Secondary FEPs that are a restatement of the primary FEP or another secondary FEP are simply identified as redundant. For secondary FEPs that are a subset (possibly with more detail provided) of the primary FEP, a brief discussion is provided. In all cases, for a complete description of the secondary FEPs, the reader is referred to the FEPs database (CRWMS M&O 2000gg).

Basis for TSPA Screening

The ongoing modeling and analysis of the EBS is documented in numerous AMRs. These AMRs represent the principal references for the discussion on how each FEP is dealt with in the TSPA. A list of the AMRs is provided in Table 7. In the following discussion on and screening of the EBS FEPs, the AMR ID number (rather than the document ID number) will be used to reference the relevant EBS AMR for that discussion. It should be noted that the key AMRs that define most of the direct feeds to the TSPA are E0010, *Physical and Chemical Environmental Abstraction Model* (CRWMS M&O 2000b); E0095, *EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000j); and E0080, *Drift Degradation Analysis* (CRWMS M&O 2000h). For the most part, the other AMRs provide supporting process modeling and analysis details that support these abstractions, but do not feed the TSPA directly. Hence they will typically not be referenced directly in the reference section of each FEP subsection.

Screening decisions for excluded FEPs often reference more detailed analyses documented in other AMRs. In several cases, screening decisions as currently documented are based exclusively on engineering judgement. Ongoing analytical and experimental research will be used to better quantify those screening decisions in the future. In other cases, certain FEPs are excluded at the present time, because neglecting the process is conservative from a dose perspective (sorption, for example). Ongoing research is also addressing selected FEPs of this nature. In both cases, the results of insights gained from this ongoing and future work may result in a particular FEP being reclassified as "Include" in the future.

Process Model Screening Considerations

In the screening of FEPs for TSPA, EBS process model considerations were used as background. Attachment 1 documents these considerations and refers to the source EBS AMR. The AMRs contributing to these considerations are (see full references in Table 7): *EBS Radionuclide Transport Model* AMR (E0050) (CRWMS M&O 2000f); *Drift Degradation Analysis* AMR (E0080) (CRWMS M&O 2000h); *Water Distribution and Removal Model* AMR (E0090) (CRWMS M&O 2000i); *Engineered Barrier System: Physical and Chemical Environmental Model* AMR (E0100) (CRWMS M&O 2000b); and *Multiscale Thermohydrologic Model* AMR (E0120) (CRWMS M&O 2000m).

It is noted that the process model considerations in Attachment 1 may differ from the TSPA considerations that are documented in this section for a given FEP. The primary reason for this is that the process model may explicitly consider a given process to allow a determination of it's impact on repository performance. Thus, it is "included" from a process modeling perspective. However, subsequent analysis of this process using the developed model may well demonstrate that the process has a negligible impact on performance, such that it is actually "excluded" from the TSPA. Also the process model considerations are preliminary, in the sense that they are subject to future refinement or enhancement as the TSPA evolves in support of a potential license application for the repository.

Relationship of FEPs to IRSR Issues

Also provided in each FEP section is a cross reference to key technical issues identified by the NRC (NRC 1999a, 1999b, 1999c, NRC 2000a, 2000b, 2000c, 2000d, 2000e, Reamer 1999) as being important for the Yucca Mountain repository. These are identified as Issue Resolution Status Report (IRSR) issues. The key technical issues and subissues are listed below. The relevance of these subissues to the EBS FEPs is identified in Sections 6.2.1 through 6.2.86. Whenever the key technical issue (CLST, for example) is identified rather than a specific subissue, all subissues apply.

Container Life and Source Term (CLST)

<u>CLST1</u>	Corrosion processes on the lifetime of the containers
<u>CLST2</u>	Mechanical failure and lifetime of the containers
<u>CLST3</u>	Spent nuclear fuel radionuclide release
<u>CLST4</u>	High-level waste radionuclide release
<u>CLST5</u>	In-package criticality
<u>CLST6</u>	Alternate EBS design effects

Evolution of the Near-Field Environment (ENFE)

ENFE1	THC processes on seepage and flow
ENFE2	Waste package chemical environment
ENFE3	Chemical environment for radionuclide release
ENFE4	THC processes on radionuclide transport through engineered and natural barriers
ENFE5	Nuclear criticality in the near field

Igneous Activity (IA)

IA1	Probability of future IA
IA2	Consequences of IA within the repository setting

Radionuclide Transport (RT)

RT1	RT through porous rock
RT2	RT through fractured rock
RT3	RT through alluvium
RT4	Nuclear criticality in the far field

Repository Design and Thermal-Mechanical Effects (RDTME)

RDTME1	Design control processes
RDTME2	Seismic design methodology
RDTME3	Thermal-mechanical effects
RDTME4	Design and long-term contribution of seals to performance

Structural Deformation and Seismicity (SDS)

SDS1	Faulting
SDS2	Seismicity
SDS3	Fracturing and structural framework
SDS4	Tectonics framework

Thermal Effects on Flow (TEF)

TEF1	FEPs related to TEF

TEF2 Thermal effects on temperature, humidity, saturation and flux

Total System Performance Assessment and Integration (TSPAI)

TSPAI1 System description and demonstration of multiple barriers

TSPAI2 Scenario analysis

TSPAI3 Model abstraction

TSPAI4 Demonstration of overall performance

Unsaturated and Saturated Flow under Isothermal Conditions (USFIC)

USFIC1 Climate change

USFIC2 Hydrologic effects of climate change

USFIC3 Present-day shallow infiltration

USFIC4 Deep percolation

USFIC5 SZ Ambient Flow and Dilution

USFIC6 Matrix diffusion

6.4.1 Excavation/Construction – YMP 1.1.02.00.00

FEP Description: This FEP is concerned with the effects associated with excavation/construction of the underground regions of the repository on the long-term behavior of the engineered and natural barriers. Excavation-related effects include changes to rock properties due to boring and blasting and chemical changes to the rock and incoming groundwater due to potential explosives residue. Excavation and other construction activities could also directly cause groundwater chemistry changes within the tunnel due to the impact of such contaminants as diesel exhaust, explosives residues, or other organic contaminants (Secondary FEP 1.1.02.00.03). Finally, oxidizing water introduced into the repository during excavation/construction could impact repository conditions/performance (Secondary FEP 1.1.02.00.04).

Screening Decision and Regulatory Basis: Excluded – Low Consequence

Screening Argument: Excavation-related effects may impact both the natural and engineered barriers in the repository. The impact on the natural barrier (i.e., rock surrounding the tunnel) may be both mechanical and chemical. The mechanical effects from construction could impact the calculation of drift degradation/rock fall. However, this is explicitly accounted for in the rock properties used for these degradation analyses (see E0080 - *Drift Degradation Analysis* (CRWMS M&O 2000h)), and thus no further analysis is required.

Any chemical effects on rock properties and/or the properties of incoming water due to residues deposited within the rock matrix fall within the scope of the NFE analysis and are not an issue relative to the EBS analysis. To the extent that incoming water properties are initially impacted by excavation-related effects, this would be provided to the EBS analysis from the NFE analysis via appropriate boundary conditions.

Additional changes to the groundwater chemistry could occur as a result of materials left/deposited within the tunnel (diesel exhaust, explosives residues, residual organic contaminants, etc.). A detailed assessment of such groundwater chemistry changes can be found in CRWMS M&O 1995b. That document determines acceptable upper bounds on materials introduced into the drift prior to closure, such that the impact of these materials has negligible consequences on repository performance. These limits represent constraints that must be adhered to during the preclosure phase of operation.

Because the emplacement drifts are situated in the unsaturated zone of the repository, any water entering the drifts will be oxidizing throughout the entire history of the repository. Thus, there are no effects associated with influx of oxidizing water during construction/excavation that are not already modeled implicitly in the TSPA.

TSPA Disposition: This FEP is excluded from the TSPA (for the EBS) on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.02.00.01, Blasting and vibration

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.02.00.02, Geochemical alteration (excavation)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.02.00.03, Groundwater chemistry (excavation)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.02.00.04, Influx of oxidizing water

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.02.00.05, Influx of oxidizing water

Relationship to Primary FEP: This FEP is completely redundant with FEP 1.1.02.00.04, but retained in FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, TEF1, TEF2, RT1

References: E0080 (CRWMS M&O 2000h)

6.4.2 Site Flooding (During Construction and Operation) – YMP 1.1.02.01.00

FEP Description: Flooding of the site during construction and operation could introduce water into the underground tunnels, which could affect the long-term performance of the repository. (Note that this is a specific example of an accident or unplanned event discussed under FEP 1.1.12.01.00.)

Screening Decision and Regulatory Basis: Excluded – Low Consequence

Screening Argument: The possibility of flooding was considered in the location of the entry ramps and surface buildings. As a result of this, the current design makes flooding of the underground areas, which would require redirection of runoff (e.g., down ramps), highly unlikely. In general, operational issues are outside the scope of the TSPA. Operation will be according to procedures acceptable to the NRC and EPA. Quality control procedures are designed to detect operational events resulting in deviations from the repository design that might affect long-term performance. Any deviation would be detected during regulator audits and inspections and be corrected before further work in the repository would be allowed to continue. Further, since any unplanned ingress of water into the repository would be detected prior to repository closure, its consequences would be evaluated to ensure that there was a negligible impact on dose. Thus, because repository flooding is mitigated through surface design, and because any partial flooding that did occur would be evaluated prior to repository closure, this FEP can be excluded on the basis of low consequence to expected dose.

TSPA Disposition: This FEP is excluded from the TSPA (for the EBS) on the basis that deviation from prescribed operational procedures would require mitigation, which would ensure that the radiological consequences are negligible.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.02.01.01, Repository flooding during operation

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.4.3 Effects of Preclosure Ventilation – YMP 1.1.02.02.00

FEP Description: The duration of preclosure ventilation acts together with waste package spacing (as per design) to control the extent of the boiling front within the NFE.

Screening Decision and Regulatory Basis: Included

Screening Argument: The early thermal history of the repository (and associated water inflow) is strongly influenced by preclosure ventilation, and these in turn have a significant impact on EBS component performance. Thus, these are important issues relative to EBS performance. However, this is primarily accounted for via the NFE boundary conditions (water influx and temperature) provided to the EBS analysis, and thus is not strictly an EBS analysis issue.

TSPA Disposition: The effects of preclosure ventilation are considered in the EBS analysis via suitable boundary conditions (temperature, flow) from the NFE analysis.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.02.02.01, Gas generation, near-field rock

Relationship to Primary FEP: This FEP is a subset of the Primary FEP that deals specifically with the introduction of gas into the saturated rock in the immediate vicinity of the repository during the preclosure phase. Because the Yucca Mountain repository design baseline has the emplacement drifts located in the UZ, the issue of gas introduction into the SZ is not relevant, and there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE1, TEF1, TEF2

References: E0095 (CRWMS M&O 2000j), E0010 (CRWMS M&O 2000b), E0105 (CRWMS M&O 2000l)

6.4.4 Undesirable Materials Left – YMP 1.1.02.03.00

FEP Description: During construction and preclosure operation of the repository there might be possibilities for leaving unwanted material in the vicinity of the radioactive waste. These materials could be of different kinds and could to some extent affect many long-term processes in the repository from canister corrosion to transport mechanisms of radionuclides. (Note that this FEP has some overlap with the issues discussed under FEP 1.1.02.00.00.)

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Materials introduced during the preclosure construction and operation phase of the repository may, if not controlled, have a conceivably unconstrained impact on groundwater chemistry within the EBS, thereby impacting corrosion processes, radionuclide transport, etc. A detailed assessment of such groundwater chemistry changes can be found in CRWMS M&O 1995b. This document determines acceptable upper bounds on materials introduced into the drift prior to closure such that the impact of these materials has negligible consequences on repository performance. These limits represent constraints that must be adhered to during the preclosure phase of operation.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.02.03.01, Decontamination materials left

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.02.03.02, Inadvertent inclusion of undesirable materials

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.5 Error in Waste or Backfill Emplacement – YMP 1.1.03.01.00

FEP Description: Deviations from the design and/or errors in waste and backfill emplacement could affect long-term performance of the repository. A specific example of such an error that has been raised involves erroneously emplacing the waste packages in the saturated zone of the repository (Secondary FEP 1.1.03.01.04). This would clearly impact the repository performance both by impacting container corrosion and failure as well as by impacting radionuclide transport.

Screening Decision and Regulatory Basis: Excluded – Low Probability (not credible, high-consequence undetected errors), Excluded - Low Consequence (other undetected errors).

Screening Argument: In general, the TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design (see Section 5.1.2). Deviations from this design during the construction phase of the repository lifetime are subject to an extensive quality control program. The reviews, inspections, and other controls associated with this program are designed to ensure that repository construction is performed within specified tolerance limits. Any deviations beyond these limits would require either an analysis to ensure that there are no adverse consequences associated with the deviation, or a correction of the problem. Thus, errors or deviations in design will be small and within the acceptable bounds specified. Such deviations are well within the variability assessment incorporated into the TSPA and the consequences to dose associated with such deviations are negligible. This issue is dealt with in broad terms in FEP 1.1.07.00.00, Repository Design, and FEP 1.1.1.08.00, Quality Control.

For this particular FEP, it is assumed that waste packages and backfill (should backfill be included in the repository design in the future) will be emplaced according to repository design (see Section 5.1.2). Alternative emplacement designs, with and without backfill have been considered, but the TSPA assumes a single emplacement strategy. Within this single emplacement strategy, the impact of uncertainties in such parameters as environmental conditions and the impact of allowable tolerances in design parameters are explicitly accounted for in the TSPA. The specific example of waste package emplacement within the wet zone of the repository is most relevant to a particular design option - vertical, in-floor borehole emplacement - that is no longer considered. The current design involves horizontal, in-drift emplacement of very large containers. Wet zones are readily detectable and thus can be avoided. Thus, this example of emplacement error, as described in the FEP description, would be exceedingly unlikely for the current Yucca Mountain design.

Based on these arguments, this FEP is excluded from the TSPA on the basis that any errors that could result in significant consequences would be detected and corrected by the quality assurance program and thus of low probability (not credible). Any errors that would remain uncorrected would be of sufficiently small magnitude that they would have negligible consequence to the expected dose.

TSPA Disposition: This FEP is excluded from the TSPA on the basis low consequence to the expected dose for any residual errors within the allowable tolerances of the quality assurance program.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.03.01.01, Inadequate backfill or compaction, voidage

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the backfill. Since there is no backfill as part of the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 1.1.03.01.02, Containers are improperly placed – on drift floor

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with one form of emplacement error. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.03.01.03, Containers are placed too close together

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with one form of emplacement error. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.03.01.04, Emplacement error – containers placed in wet zone

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with emplacement errors in the wet zone. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST1, CLST2, ENFE1, ENFE4, TEF1, TEF2

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.4.6 Repository Design – YMP 1.1.07.00.00

FEP Description: This category contains FEPs related to the design of the repository, and the ways in which the design contributes to long-term performance. Changes to or deviations from the specified design may affect the long-term performance of the disposal system.

Screening Decision and Regulatory Basis: Included (all aspects of FEP not specifically excluded), Excluded – Low Consequence (deviations from design)

Screening Argument: All important aspects of the EDA-II repository design are accounted for in the TSPA. Individual elements of this design (drip shield, pedestal, invert, ground support, etc.) are covered by other EBS FEPs. In general, the TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design (see Section 5.1.2). Deviations from this design during the construction phase of the repository lifetime are subject to an extensive quality control program. The reviews, inspections, and other controls associated with this program are designed to ensure that repository construction is performed within specified tolerance limits. Any deviations beyond these limits would require either an analysis to ensure that there are no adverse consequences associated with the deviation, or a correction of the problem. Thus, errors or deviations in design will be small and within the acceptable bounds specified. Such deviations are well within the variability assessment incorporated into the TSPA. This issue is also covered in FEP 1.1.1.08.00, Quality Control.

Based on these arguments, this FEP is excluded from the TSPA on the basis that any deviations from the repository design would be of sufficiently small magnitude that they would have negligible consequences to the expected dose.

TSPA Disposition: The TSPA is based on an assumption (see Section 5.1.2) that the repository will be constructed, operated, and closed according to design. Modifications and/or deviations from the design are excluded on the basis of low consequence to the expected dose (significant deviations from the design will be either corrected prior to repository closure or analyzed to ensure there is no dose impact).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.07.00.01, Poorly designed repository

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness. It deals with a repository design that does not meet the design criteria and/or is shown to be unsafe. Such a repository would not go into operation.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.07.00.02, Design modification

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.07.00.03, HLW panels (siting)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with a repository design issue unique to a repository design in crystalline rock (location of HLW panels relative to faults or other disturbed zones in the crystalline rock). Since this is not relevant to the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 1.1.07.00.04, TRU silos (siting)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with a repository design issue unique to the WIPP site, the use of cementitious backfill. Since the use of cementitious backfill is not part of the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 1.1.07.00.05, Access tunnels and shafts

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with a repository design issue unique to a repository design in crystalline rock. Because of the generally low permeability of the crystalline rock, concern was raised about access tunnels crossing rock zones of higher permeability, with a suggestion for access tunnel orientation to minimize flow along these tunnels. Since this issue is not relevant to the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 1.1.07.00.06, Design and Construction FEPs

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.07.00.07, Design and Construction

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.07.00.08, Design and Construction FEPs

Relationship to Primary FEP: This FEP is completely redundant with secondary FEP 1.1.07.00.06, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: All

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.4.7 Quality Control – YMP 1.1.08.00.00

FEP Description: This category contains FEPs related to quality assurance and control procedures and tests during the design, construction, and operation of the repository, as well as the manufacture of the waste forms, containers, and engineered features. Lack of quality control could result in material defects, faulty waste package fabrication, and faulty or non-design-standard construction, all of which may lead to reduced effectiveness of the engineered barriers.

Screening Decision and Regulatory Basis: Included (defects and deviations specifically identified), Excluded – Low Consequence (defects and deviations except for those specifically identified)

Screening Argument: In general, the TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design (see Section 5.1.2). Deviations from this design during the construction phase of the repository lifetime are subject to an extensive quality control program. The reviews, inspections, and other controls associated with this program are designed to ensure that repository construction is performed within specified tolerance limits. Any deviations beyond these limits would require either an analysis to ensure that there are no adverse consequences associated with the deviation, or a correction of the problem. Thus, errors or deviations in design will be small and within the acceptable bounds specified. Such deviations are well within the variability assessment incorporated into the TSPA.

Residual uncertainty remaining after implementation of quality control has been included in the TSPA in the performance analysis of key design features. Thus, juvenile failure of some fraction of the waste packages is considered to account for possible welding defects.

TSPA Disposition: The TSPA is based on an assumption that the repository will be constructed, operated, and closed according to design (see Section 5.1.2) under an acceptable quality control plan. Deviations from the design due to poor quality control are excluded on the basis of low consequence to expected dose (undetected deviations from the planned design will be sufficiently small). Certain material defects (juvenile failure of some number of waste packages) are considered. However, other such defects due to poor quality control are excluded on the basis of low consequence to expected dose (undetected defects will be sufficiently small).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.08.00.01, Poorly constructed repository

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.08.00.02, Material defects

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.08.00.03, Common cause failures

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.08.00.04, Poor quality construction

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.08.00.05, Quality Control

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.08.00.06, Quality Control

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.08.00.07, Drains, installed to divert water around containers, are improperly placed

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with a design feature unique to the WIPP repository (drains over canisters for water diversion). Since the use of such drains is not part of the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: All

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.4.8 Accidents and Unplanned Events During Operation – YMP 1.1.12.01.00

FEP Description: The long-term performance of the disposal system might be seriously affected by unplanned or improper activities that take place during construction, operation, and closure of the repository.

Screening Decision and Regulatory Basis: Excluded – Low Consequence

Screening Argument: In general, operational issues are outside the scope of the TSPA. Operation will be according to procedures acceptable to the NRC and EPA. Quality control procedures are designed to detect operational events resulting in deviations from the repository design that might affect long-term performance. Any deviation would be detected during regulator audits and inspections and would be analyzed and/or corrected before further work in the repository would be allowed to continue. Examples of accidents and unplanned events include: repository flooding, sabotage, handling damage to waste containers, leaks of undesirable materials, and explosions.

For the purposes of the TSPA, the effects of these types of events are assumed to be corrected before closure (see Section 5.1.2). Therefore, accidents and unplanned events during the operational phase are excluded from the TSPA on the basis of low consequence to the expected dose.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence to the expected dose, because operational procedures require suitable mitigation of the effects of any unexpected incidents.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.12.01.01, Preclosure events

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.12.01.02, Sabotage and improper operation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.12.01.03, Accidents during operation

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.12.01.04, Accidents during operation

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.12.01.05, Handling accidents

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.1.12.01.06, Oil or organic fluid spill

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion. Note that it is also directly related to Primary FEP 1.1.02.03.00, and discussed therein

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4

References: Dyer 1999, 64 FR 8640, 64 FR 46976

6.4.9 Retrievability – YMP 1.1.13.00.00

FEP Description: This category contains FEPs related to design, emplacement, operational, or administrative measures that might be applied or considered in order to enable or ease retrieval of wastes. There may be a requirement to retrieve all or part of the waste stored in the repository (e.g., to recover valuable fissile materials or to replace defective containers).

Screening Decision and Regulatory Basis: Included

Screening Argument: This FEP is explicitly considered in the design requirements for the repository, as discussed under TSPA disposition.

TSPA Disposition: Retrievability is implicitly considered in all phases of the TSPA through the repository design parameters. Regulation requires that the repository be designed in such a way that removing the waste is not precluded for a reasonable period of time after emplacement. The current repository design (CRWMS M&O 2000bb) allows for the possibility of keeping the repository open at least 100 years after the initiation of emplacement, with a reasonable expectation that the repository could, with appropriate maintenance, be kept open for up to 300 years after the initiation of waste emplacement. Aspects of the repository design related to waste retrievability (such as the design of the drifts and emplacement of the waste packages) are included in the repository design that is used as the basis for the TSPA modeling.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.1.13.00.01, Retrievability

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: All

References: CRWMS M&O 2000bb

6.4.10 Igneous Intrusion Into Repository – YMP 1.2.04.03.00

FEP Description: Magma from an igneous intrusion may flow into the drifts and extend over a portion of the repository site, forming a sill. The sill could be limited to the drifts or a continuous sill could form along the plane of the repository, bridging between adjacent drifts.

Note that this FEP also encompasses FEP ebs # 36 from Table 4.

Screening Decision and Regulatory Basis: Included

Screening Argument: The impact of an igneous intrusion into the repository is significant in that it changes the fundamental response of the EBS.

TSPA Disposition: This FEP is included in TSPA as documented in the disruptive events FEPs AMR (CRWMS M&O 2000s).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 1.2.04.03.01, Sill provides a permeable flow path

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.2.04.03.02, Sill provides a flow barrier

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.2.04.03.03, Sill intrudes repository openings

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.2.04.03.04, Volcanism

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 1.2.04.03.05, Intruding dikes

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: IA1, IA2

References: CRWMS M&O 2000s

6.4.11 Corrosion of Waste Containers – YMP 2.1.03.01.00

FEP Description: Corrosion may contribute to waste package failure. Corrosion is most likely to occur at locations where water drips on the waste packages, but other mechanisms should be considered.

Screening Decision and Regulatory Basis: Included

Screening Argument: The time-dependent water distribution and the chemistry of this water relative to waste package corrosion are important parameters relative to repository performance. Special consideration of anoxic corrosion (FEP 2.1.03.01.04) can be excluded from the TSPA on the basis of low probability (not credible), because for a repository located in the unsaturated zone, the connection to the atmosphere ensures an oxidizing environment at all times.

TSPA Disposition: The TSPA corrosion model considers general corrosion and stress corrosion cracking in both wet and dry environments for the drip shield and waste package materials. The treatment of these phenomena is part of the WP analysis effort, and a discussion of their treatment may be found in the FEPs summary discussion for WP documented in CRWMS M&O 2000w. The EBS analysis provides two key sets of parameters to the WP analysis; the time-dependent rate of water contact with both drip shield and waste package (as described in E0095 (CRWMS M&O 2000j)), and the chemistry of this water (as described in E0010 (CRWMS M&O 2000b)).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.03.01.01, Metallic corrosion

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.02, Corrosion on wetting (of waste container)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (corrosion under wet conditions), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.03, Oxic corrosion (of waste container)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (corrosion due to oxygen in the repository atmosphere), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.04, Anoxic corrosion (of waste container)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with corrosion following the depletion of oxygen. This issue is not relevant to a repository located in the UZ such as the Yucca Mountain design baseline. Thus, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.03.01.05, Total corrosion rate (of waste container)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.06, Corrosion of copper canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the issue of copper corrosion. Because there is no use of copper canisters in the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that thjs FEP will occur.

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.03.01.07, Corrosion of steel vessel

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the issue of steel inner barrier corrosion following the failure of the outer copper layer. Because there is no use of copper canisters in the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur.

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.03.01.08, Container metal corrosion

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.09, Corrosion (of waste container)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.10, Uniform corrosion (of waste container)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (uniform corrosion) and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.11, Corrosive agents, Sulfides, oxygen, etc.

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.03.01.12, Water turnover, copper canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the issue of water intrusion into the gap between an outer copper canister and an inner steel one. Because this WP design is not used in the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that thjs FEP will occur.

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: CLST1, ENFE2

References: E0095 (CRWMS M&O 2000j), E0010 (CRWMS M&O 2000b), CRWMS M&O 2000w

6.4.12 Container Healing – YMP 2.1.03.10.00

FEP Description: Pits and holes in waste packages could be partially or fully plugged by chemical or physical reactions during or after their formation, affecting corrosion processes and water flow and radionuclide transport through the breached container. Passivation by corrosion products is a potential mechanism for container healing.

Screening Decision and Regulatory Basis: Excluded – Low Consequence (Favorable consequences are neglected by excluding this FEP)

Screening Argument: For purposes of the EBS response analysis, the timing of waste package failure is provided by the results of the WP analysis (CRWMS M&O 2000v) as input into the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j). While the potential for container healing is inherently a WP analysis issue (see WP FEPs discussion (CRWMS M&O 2000w)), the EBS analysis does provide to the WP analysis the chemistry of the groundwater contacting both the drip shield and waste package. This is discussed in the EBS *Physical and Chemical Environmental Abstraction*, E0010 (CRWMS M&O 2000b).

Container failure and breach (when liquids can leave a container) are described by a distribution function for analyses (CRWMS M&O 2000y). This distribution function is based on failure of the WPs due to corrosion. Possible healing of the breaches in the failed WPs would serve to delay the release of radionuclides relative to the time of failure. Thus, exclusion of this effect may be considered conservative. A more comprehensive discussion of this FEP is presented in the AMR dealing with WP and drip shield degradation FEPs (CRWMS M&O 2000w).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible adverse consequence to dose.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.03.10.01, Corrosion products (physical effects)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (corrosion products on the surface of the canisters seal any cracks), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST1, ENFE2, RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j), CRWMS M&O 2000v, CRWMS M&O 2000w

6.4.13 Container Failure (Long-term) – YMP 2.1.03.12.00

FEP Description: Waste packages and drip shields have a potential to fail over long periods of time by a variety of mechanisms, including general corrosion, stress corrosion cracking, pit corrosion, hydride cracking, microbially-mediated corrosion, internal corrosion, and mechanical impacts.

Screening Decision and Regulatory Basis: Included

Screening Argument: Long-term failure of the WPs and drip shields must be accounted for in TSPA analyses as this defines the timing of radionuclide release and transport.

TSPA Disposition: WP and drip shield failure is calculated explicitly as part of the waste package analysis (CRWMS M&O 2000v). A discussion of these issues relative to the WP analysis may be found in the WP FEPs (CRWMS M&O 2000w). The EBS TSPA models provide critical inputs for that analysis including the timing of water contact as discussed in E0095 (CRWMS M&P 2000j), the chemistry of the water as discussed in E0010 (CRWMS M&O 2000b), and the timing and impact of rock-fall as discussed in E0080 (CRWMS M&O 2000h). Note that the properties of the failed containers relative to their impact on EBS performance are addressed as part of FEP 2.1.08.07.00, and the chemical buffering effects of the failed containers are addressed as part of FEP 2.1.09.02.00.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.03.12.01, Canister failure (reference)

Relationship to Primary FEP: This FEP deals with the issue of canister failure, but for a specific international repository design, and provides a specific estimate of canister lifetime (100 years). Since this design is not relevant to the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.03.12.02, Long-term physical stability (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST1, CLST2, ENFE2, ENFE3

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j), E0080 (CRWMS M&O 2000h), CRWMS M&O 2000v, CRWMS M&O 2000w

6.4.14 Preferential Pathways in the Backfill – YMP 2.1.04.01.00

FEP Description: Preferential pathways for flow and diffusion may exist within the backfill and may affect long-term performance of the waste packages. Backfill may not preclude hydrological, chemical, and thermal interactions between waste packages within a drift.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, it would represent a preferential pathway for seepage into the drift because it may tend to funnel fluid into the emplacement drift due to its capillarity. This has an important impact on water contact with the drip shield and the resulting corrosion. In addition, the potentially high water content of the backfill impacts the in-drift thermal response due to waste package heat generation.

The effect of the backfill on water transport within the drift would have to be accounted for in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j). Most notably, this would need to consider the capillary effects of the backfill as a mechanism for enhanced water transport to the drip shield.

Note that this FEP also encompasses FEPs ebs # 5 and 18 from Table 4.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.04.01.01, Interaction and diffusion between canisters (and buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.01.02, Flow through buffer/backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.01.03, Flow through buffer/backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), CRWMS M&O 2000bb

6.4.15 Physical and Chemical Properties of Backfill – YMP 2.1.04.02.00

FEP Description: The physical and chemical properties of the backfill may affect groundwater flow, waste package and drip shield durability, and radionuclide transport in the waste disposal region.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, the properties of the backfill would have a significant effect on the transport of water to the drip shield, and hence must be considered explicitly in the TSPA.

The porosity and permeability of quartz sand backfill (and crushed tuff in the invert) would need to be represented in the thermal/hydrological response of the WPs and drip shields in the emplacement drifts as discussed in E0120 (CRWMS M&O 2000m). These calculations define the fluid flux due to capillarity (if it exists), the temperature and relative humidity at the WP, and the potential for condensation on the underside of the drip shield due to evaporation from the invert. The effects of the chemical properties of sand backfill and crushed tuff on transport would be ignored in the TSPA analyses because of two conservative assumptions that would be made: (1) there is no sorption in the invert or in sand backfill, and (2) chemical changes to the backfill seem likely to divert seepage away from the WP. The chemical properties of the backfill would, however, need to be considered in the analysis of seepage/backfill chemical interactions as discussed in E0010 (CRWMS M&O 2000b).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.04.02.01, Backfill characteristics

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.02, Inhomogeneities (properties and evolution in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.03, Chemical alteration of buffer/backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.04, Backfill physical composition

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.05, Backfill chemical composition

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.06, Chemical degradation of backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.07, Backfill material deficiencies

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.08, Near-field buffer chemistry

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.09, Water chemistry, tunnel backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.02.10, Backfill effects on Cu corrosion

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with backfill. Since there is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0120 (CRWMS M&O 2000m), E0095 (CRWMS M&O 2000j), CRWMS M&O 2000bb

6.4.16 Erosion or Dissolution of Backfill – YMP 2.1.04.03.00

FEP Description: Solid material in buffer or backfill is carried away by flowing groundwater, either by erosion of particulate matter or by dissolution.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, one material that could be used is quartz sand. Thus, it will not be highly soluble and no significant loss due to dissolution is anticipated. Furthermore, flow rates in the unsaturated environment of the repository will be too low to cause significant erosion. Any limited erosion that does occur would be expected to have negligible impact on repository performance. Wicking of water to the drip shield surface would not be impacted by a slight reduction in backfill volume. Further, the degree of backfill erosion would not be expected to be sufficient to reduce drip shield protection from rock fall. Thus, even with backfill included in the design, this FEP would be excluded on the basis of low consequence.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.04.03.01, Erosion of buffer/backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), CRWMS M&O 2000bb

6.4.17 Mechanical Effects of Backfill – YMP 2.1.04.04.00

FEP Description: Backfill may alter the mechanical evolution of the drift environment by providing resistance to rock creep and rock fall, by changing the thermal properties of the drift, or by other means. Impacts of the evolution of the properties of the backfill itself should be considered.

Note that this FEP also encompasses FEP ebs # 5 from Table 4.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, it would be a key component of the EBS and as such must be explicitly accounted for in the TSPA. The presence of the backfill would need to be explicitly included in estimating the mechanical response of the drip shield to rockfall by distributing the load from a rockfall over a larger area of the drip shield. It would also need to be included in evaluating the waste package environment because the backfill would be assumed to fall through any penetrations through the drip shield and form a continuous fluid path between the backfill and the waste package. Finally, in addition to the direct impacts delineated above, the backfill would also influence the thermal response of the repository, which in turn could influence the character of rock fall.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

> **FEP Number and Name: 2.1.04.04.01, Mechanical failure of buffer/backfill**
>
> <u>Relationship to Primary FEP:</u> This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).
>
> <u>Screening and Disposition:</u> Same as the Primary FEP.
>
> **FEP Number and Name: 2.1.04.04.02, Mechanical impact/failure, buffer/backfill**
>
> <u>Relationship to Primary FEP:</u> This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).
>
> <u>Screening and Disposition:</u> Same as the Primary FEP.

IRSR Issues: CLST2, CLST6

References: E0080 (CRWMS M&O 2000h), CRWMS M&O 2000bb

6.4.18 Backfill Evolution - YMP 2.1.04.05.00

FEP Description: Properties of the backfill may change through time, due to processes such as silica cementation, alteration of minerals, thermal effects, and physical compaction. These changes could then affect the movement of water and radionuclides in the backfill.

Note that this FEP also encompasses FEP ebs # 5 from Table 4.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, the evolution of backfill properties would potentially need to be considered. However, as discussed below, the neglect of such changes in the current TSPA would be conservative relative to water transport to the waste packages and thus radionuclide transport to the unsaturated zone (UZ).

Backfill affects the performance of the drip shields and WPs in two ways: It acts to mitigate the impact of rock fall, and it serves to create a uniform water distribution via wicking of water through this material. While localized cementation of the backfill material would not be expected for the temperatures in the EBS, even if such localized agglomeration did occur, it would have an insignificant impact on repository performance. Mitigation of rockfall impacts would still occur. In addition, such localized cementation would on average serve to reduce the rate of water transport to the drip shield surface. Thus, excluding such an effect would be conservative. The same argument holds for the formation of a low permeability rind on the top of the backfill. Such a rind will tend to divert seepage from the drip shield and WP, and thus it is conservative to neglect this effect. Thus, the physical properties (porosity, permeability) of the backfill could be assumed to remain constant over time in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j). Detailed chemical studies are evaluating the geochemical environment during the first few thousand years, when the backfill will be very hot and evaporation will generate strong ionic solutions and precipitated salts in the backfill or on the drip shield. The chemical processes in the backfill would need to be assessed in the seepage/backfill interaction analysis in E0010 (CRWMS M&O 2000b).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.04.05.01, Hydrothermal alteration (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in

10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.05.02, Small pieces of backfill undergo phase changes when heated and welded together

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.05.03, Thermal degradation of buffer/backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST2, ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j), CRWMS M&O 2000bb

6.4.19 Properties of Bentonite – YMP 2.1.04.06.00

FEP Description: This category contains FEPs specific to the properties of bentonite buffers. Because the Yucca Mountain design does not include bentonite backfill, all FEPs in this category are irrelevant to the YMP TSPA.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: Bentonite is not part of the design baseline (CRWMS M&O 2000bb) for Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.04.06.01, Bentonite swelling pressure

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.02, Bentonite erosion

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.03, Bentonite plasticity

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.04, Bentonite porewater chemistry

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.05, Mineralogical alteration – short term (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.06, Mineralogical alteration – long term (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.07, Bentonite cementation

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.08, Quality control (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.09, Poor emplacement of buffer

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.10, Organics/contamination of bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in

10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.11, Coagulation of bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.12, Dilution of buffer/backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.13, Sedimentation of bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.14, Swelling of tunnel backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.15, Swelling pressure (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.16, Degradation of bentonite by chemical reactions

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.17, Colloid generation (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.18, Coagulation of bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.19, Sedimentation of bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.20, Swelling of bentonite into tunnels and cracks

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.21, Uneven swelling of bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.22, Thermal effects on the buffer material

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.23, Bentonite emplacement and composition

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.24, Thermal evolution (in buffer/backfill)

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.25, Bentonite saturation

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.26, Buffer impermeability

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.27, Bentonite swelling

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.28, Resaturation of bentonite buffer

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.29, Resaturation of tunnel backfill

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in

10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.30, Effects of bentonite on groundwater chemistry

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.31, Canister/bentonite interaction

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.32, Interaction with cement components

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.33, Water chemistry, bentonite buffer

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.34, Gas transport in bentonite

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.06.35, Effect of bentonite swelling on EDZ

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: None

References: CRWMS M&O 2000bb

6.4.20 Buffer Characteristics – YMP 2.1.04.07.00

FEP Description: This category contains FEPs specific to repository designs that include chemical buffering agents in the waste disposal region. The Yucca Mountain design does not include buffering agents, and all FEPs in this category are irrelevant to the YMP TSPA.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.04.07.01, Buffer additives

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.07.02, Buffer evolution

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.07.03, Faulty buffer emplacement

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.07.04, Saturation of sorption sites

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.04.07.05, Perturbed buffer material chemistry

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: None

References: CRWMS M&O 2000bb

6.4.21 Diffusion in Backfill – YMP 2.1.04.08.00

FEP Description: Diffusion processes in backfill may affect waste package performance and radionuclide transport.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, diffusion in backfill could still be excluded from the TSPA on the basis of low consequence. A backfill material such as quartz sand would be upstream of the waste package from a flow viewpoint. In this situation, radionuclides could only reach the backfill when the downward advective flux through the drip shield was negligible and when there was a continuous fluid pathway that allowed upward diffusion across the gap between drip shield and waste package. When the drip shield was intact there would be no flow path. When the drip shield was breached there would be a flow path (through backfill sitting on the waste package); however, upward diffusion would be negligible in comparison to downward advection. Diffusion through the backfill could therefore still be screened out for the TSPA analyses.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

IRSR Issues: ENFE1, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), CRWMS M&O 2000bb

6.4.22 Radionuclide Transport Through Backfill – YMP 2.1.04.09.00

FEP Description: Radionuclide transport in the drift environment may be affected by the presence of backfill. Transport of both dissolved and colloidal species, advective and diffusive effects and sorption processes should be considered.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: There is no backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Should backfill be included in the repository design in the future, radionuclide transport in backfill could be excluded from the TSPA on the basis of low consequence. A quartz sand backfill material would be upstream of the waste package from a flow viewpoint. In this situation, radionuclides could only reach the backfill when the downward advective flux through the drip shield was negligible and when there was a continuous fluid pathway that allowed upward diffusion across the gap between drip shield and waste package. When the drip shield was intact there would be no flow path. When the drip shield was breached there would be a flow path (through backfill sitting on the waste package); however, upward diffusion would be negligible in comparison to downward advection and transport. Radionuclide transport through the backfill could therefore be screened out for the TSPA analyses.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

> **FEP Number and Name: 2.1.04.09.01, Transport and release of nuclides, bentonite buffer**
>
> Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).
>
> Screening and Disposition: Same as the Primary FEP.
>
> **FEP Number and Name: 2.1.04.09.02, Transport and release of nuclides, tunnel backfill**
>
> Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with buffer/backfill. Since there is no backfill and/or buffer used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).
>
> Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), CRWMS M&O 2000bb

6.4.23 Degradation of Cementitious Materials in Drift – YMP 2.1.06.01.00

FEP Description: Degradation of cementitious material used for any purposes in the disposal region may affect long-term performance through both chemical and physical processes. Degradation may occur by physical, chemical, and microbial processes.

Note that this FEP also encompasses FEPs ebs # 22 and 26 from Table 4.

Screening Decision and Regulatory Basis: Included (drift degradation), Excluded – Low Consequence (impact on seepage chemistry)

Screening Argument: Degradation of the cement grout around the rock bolts has two potentially important effects on repository performance; the impact on drift stability/degradation and the impact on water chemistry due to evolved cement leachate. The impact of cement leachate on seepage chemistry is specifically dealt with in FEP 2.1.09.01.00, and excluded there based on low consequence.

TSPA Disposition: The effect of ground control devices (the cement grout around rock bolts for this particular FEP) and their associated degradation is, however, considered explicitly in the drift degradation analysis, E0080 (CRWMS M&O 2000h). Relative to drift degradation analysis, these rock reinforcements impact the timing and associated size distribution of potential rock fall. For purposes of TSPA, the effects of ground control devices are conservatively ignored subsequent to repository closure. Thus, failure of these devices is included in a conservative bounding manner (instantaneous failure).

This FEP is excluded from the TSPA on the basis of low consequences.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.06.01.01, Physio-chemical degradation of concrete

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.06.01.02, Seal chemical composition

Relationship to Primary FEP: This FEP is a subset of the Primary FEP. The chemical composition of the grout is explicitly considered in the analyses cited as a basis for the exclusion screening argument under FEP 2.1.09.01.00.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.06.01.03, Microbial growth on concrete

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, but is also directly related to FEP 2.1.10.01.00, biological activity in waste and EBS. Cementitious materials are considered as part of the biological activity analysis in the *In-Drift Microbial Communities* AMR, E0040 (CRWMS M&O 2000d).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST1, ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.24 Effects of Rock Reinforcement Materials – YMP 2.1.06.02.00

FEP Description: Degradation of rock bolts, wire mesh, and other materials used in ground control may affect the long-term performance of the repository.

Note that this FEP also encompasses FEPs ebs # 12, 21, 22, and 26 from Table 4.

Screening Decision and Regulatory Basis: Included (drift degradation), Excluded – Low Consequence (impact on seepage chemistry)

Screening Argument: Degradation of ground control materials has two potentially important effects on repository performance; the impact on drift stability/degradation and the impact on water chemistry due to evolved corrosion products. The impact of rock reinforcement material corrosion products on seepage chemistry is specifically dealt with in FEP 2.1.09.02.00, and excluded there based on low consequence.

TSPA Disposition: The effect of ground control devices (rock bolts and wire mesh for this particular FEP) and their associated degradation is, however, considered explicitly in the drift degradation analysis, E0080 (CRWMS M&O 2000h). Relative to drift degradation analysis, these rock reinforcements impact the timing and associated size distribution of potential rock fall. For purposes of TSPA, the effects of ground control devices are conservatively ignored subsequent to repository closure. Thus, failure of these devices is included in a conservative bounding manner (instantaneous failure).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

> **FEP Number and Name: 2.1.06.02.01, Degradation of rock reinforcement and grout**
>
> <u>Relationship to Primary FEP:</u> This FEP is redundant, but retained in the FEP list for completeness.
>
> <u>Screening and Disposition:</u> Same as the Primary FEP.

IRSR Issues: CLST1, CLST2, ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0080 (CRWMS M&O 2000h)

6.4.25 Degradation of the Liner – YMP 2.1.06.03.00

FEP Description: Degradation of materials used to line the drifts may occur by physical, chemical, or microbial processes, and may affect long-term performance.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: No liner is planned for the repository (other than the steel mesh for ground support) (CRWMS M&O 2000bb). Thus, there is less than one chance in 10,000 in

10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

IRSR Issues: None

References: CRWMS M&O 2000bb

6.4.26 Flow Through the Liner – YMP 2.1.06.04.00

FEP Description: Groundwater flow may occur through the liner.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: No liner is planned for the repository (other than the steel mesh for ground support) (CRWMS M&O 2000bb). Thus, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.06.04.01, Fracture flow through the liner

Relationship to Primary FEP: This secondary FEP is a subset of the primary FEP dealing with the liner. Since there is no liner used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: None

References: CRWMS M&O 2000bb

6.4.27 Degradation of Invert and Pedestal – YMP 2.1.06.05.00

FEP Description: Degradation of the materials used in the invert and the pedestal supporting the waste package may occur by physical, chemical, or microbial processes, and may affect the long-term performance of the repository.

Note that this FEP also encompasses FEPs ebs # 1, 5, 8, 9, and 11 from Table 4.

Screening Decision and Regulatory Basis: Excluded – Low Consequence (Invert), Included (Pedestal)

Screening Argument: Physical degradation of the invert and invert materials has been screened out of the TSPA based on low consequence. The invert is a minor barrier to flow in comparison to the drip shield, waste package, and unsaturated zone beneath the drift. During the period when diffusion dominates radionuclide transport through the invert, the invert diffusion barrier does impact calculated dose. However, this period is relatively short in duration, and peak doses at that time are low compared to times when advective flow through the invert is important. Thus, changes to the invert diffusion characteristics would still have a negligible impact on peak dose. Invert porosity is not expected to change significantly due to any known degradation mechanisms. Any changes to the invert structure (e.g., consolidation and precipitation) that do occur are likely to plug flow paths through the invert and increase the likelihood of further mineral precipitation and filtering. Thus, advective transport of radionuclides through the invert would likely be reduced if invert degradation were accounted for. Based on these arguments, this FEP can be neglected on the basis of low (adverse) consequence to dose.

TSPA Disposition: Physical degradation of the pedestal is an important process because (1) the waste package will be in direct contact with the invert after the pedestal collapses, and (2) the waste package may roll off a degraded pedestal and impact the drip shield during a seismic event. To account for potential pedestal failure, the radionuclide transport abstraction for the EBS, E0095 (CRWMS M&O 2000j) conservatively assumes that the waste package is in direct contact with the invert at all times. By considering instantaneous pedestal failure in this manner, no credit is taken for the additional diffusion barrier associated with radionuclide transport within a thin water film on the pedestal surface. Thus, pedestal failure is included in TSPA in a bounding manner (instantaneous failure).

Pedestal failure may also result in the waste package impacting the drip shield, leading to drip shield separation. This aspect of pedestal failure is dealt with explicitly in FEP 2.1.07.03.00, and excluded from TSPA based on low consequence to dose. The TSPA model for drip shield separation demonstrates that the impact of such contact between the waste package and drip shield is incorporated in the large uncertainty in the seismic displacement model for the drip shield (CRWMS M&O 2000j).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.06.05.01, Cementitious invert

Relationship to Primary FEP: This FEP is a subset of the Primary FEP. However, since there is no cementitious invert used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: CLST2, ENFE1, RT1, RDTME1, RDTME2, RDTME3

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j)

6.4.28 Effects and Degradation of Drip Shield – YMP 2.1.06.06.00

FEP Description: The drip shield will affect the amount of water reaching the waste package. Behavior of the drip shield in response to rockfall, ground motion, and physical, chemical degradation processes should be considered. Effects of the drip shield on the disposal region environment (for example, changes in relative humidity and temperature below the shield) should be considered for both intact and degraded conditions. Degradation processes specific to the chosen material should be identified and considered. For example, oxygen embrittlement should be considered for titanium drip shields.

Note that this FEP also encompasses FEPs ebs # 2, 9, 10, 11, 15, 17, 19, 20, 24, 30, 31, and 32 from Table 4. A particular issue related to the impact of the drip shield on water contacting the WP (due to condensation) is discussed in FEP 2.1.08.14.00.

Screening Decision and Regulatory Basis: Included

Screening Argument: The drip shield is an important element of the EBS, and as such its as-designed function and degradation must be explicitly considered in the TSPA. Certain aspects of this functionality (degradation of the drip shield due to chemical processes) are considered directly in the WP analysis (see WP FEPs summary (CRWMS M&O 2000w)). However, the remaining aspects of drip shield behavior are considered as part of the EBS analysis.

TSPA Disposition: The EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j) explicitly considers the impact of the drip shield on flow. Prior to drip shield failure, no direct pathway for water flow to the waste package exists. However, the potential for condensation of water on the underside of the drip shield and the subsequent dripping of this condensate on the waste packages is considered. Failure of the drip shield is provided via the WP analysis outputs (CRWMS M&O 2000v) for chemically-induced failures or is explicitly considered as part of the EBS analysis for drift shield separation due to seismic events (CRWMS M&O 2000j). Subsequent to the calculation of such failures, fluid can reach the waste packages directly. For chemically-induced failures (corrosion), the EBS analysis provides directly the chemical environment on these structural surfaces (CRWMS M&O 2000x), which has a key influence on the rate of such corrosion. The effects of the corrosion products associated with drip shield degradation on seepage water chemistry are analyzed as part of the corrosion products analysis in E0010 —(CRWMS M&O 2000b).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.06.06.01, Oxygen embrittlement of Ti drip shield

<u>Relationship to Primary FEP:</u> This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion. Note that this issue is most relevant to the issue of mechanical failure of the drip shield, which is discussed under FEPs 2.1.07.01.00, rockfall, and 2.1.07.02.00, mechanical degradation or drift collapse.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST1, CLST2, ENFE2, RT1, SDS

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j), CRWMS M&O 2000v, CRWMS M&O 2000w, CRWMS M&O 2000x

6.4.29 Effects at Material Interfaces – YMP 2.1.06.07.00

FEP Description: Physical and chemical effects that occur at the interfaces between materials in the drift, such as at the contact between the backfill and the drip shield, may affect the performance of the system.

Note that this FEP also encompasses FEPs ebs # 9 and 11 from Table 4.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: The basic chemical processes that occur at phase boundaries (principally liquid/solid) are included in the geochemical modeling supporting E0010 (CRWMS M&O 2000b) and its associated submodel AMRs. Solid/solid contact either does occur or could occur between the drip shield and the invert and/or backfill (if included in the YMP design), between the waste package and the invert and/or backfill (if included in the YMP design); between the pedestal and the waste package and/or drip shield; and between the waste form and any of the other EBS component materials. Since these materials are all relatively inert, no solid/solid interaction mechanisms have been identified that are significant relative to the basic seepage water induced corrosion of the EBS components.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

IRSR Issues: RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j)

6.4.30 Rockfall (Large Block) – YMP 2.1.07.01.00

FEP Description: Rockfalls may occur that are large enough to mechanically tear or rupture waste packages.

Note that this FEP also encompasses FEPs ebs # 6, 9, and 11 from Table 4.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Large-block rockfall is possible only after failure of ground support (expected to be wire mesh and rock bolts). Such blocks could be set loose during the thermal period when thermal expansion causes considerable compressive forces and reorientation of the principal stresses. While rockfall on the WPs and drip shield is a high probability event, such rockfall is excluded from the TSPA based on the low consequences associated with such rockfall. An analysis of the possible formation of key blocks within the repository horizon has been provided in the *Drift Degradation Analysis* AMR, E0080 (CRWMS M&O 2000h). Block failure due to seismic and thermal effects has also been analyzed in that document to determine characteristic sizes for potential falling rocks.

Based on insights from these types of results, a design basis rock size can be defined, which represents a reasonable size bound for expected rockfall. Using such a design basis rockfall source term, an analysis of the waste packages (CRWMS M&O 2000cc, CRWMS M&O 2000dd, CRWMS M&O 2000ee) and drip shields (CRWMS M&O 2000ff) has been performed to develop a design capable of surviving the impacts of rockfall. These results demonstrate that the drip shield and WPs survive for the design basis rock size at Yucca Mountain. In other words, rock fall will occur, but the size of the rocks expected to impact the drip shield and WPs is too small to cause damage that would lead to earlier radionuclide release. Thus, because the design of both the waste packages and drip shield is required to meet the expected rock fall threat, the consequences of rockfall can be excluded on the basis of low consequence. While the design basis rock size cannot be proven to be the largest possible rock size, rock fall involving rocks of larger size is expected to occur with sufficiently low probability that it can be neglected.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.07.01.01, Rockbursts in container holes

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the maximum initial momentum of a rock fragment. It is explicitly considered in the analyses that form the basis for the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.01.02, Cave ins

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.01.03, Cave in (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.01.04, Roof falls

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST2, RDTME, SDS

References: E0080 (CRWMS M&O 2000h), CRWMS M&O 2000bb, CRWMS M&O 2000cc, CRWMS M&O 2000dd, CRWMS M&O 2000ee, CRWMS M&O 2000ff

6.4.31 Mechanical Degradation or Collapse of Drift – YMP 2.1.07.02.00

FEP Description: Partial or complete collapse of the drifts, as opposed to discrete rockfall, could occur as a result of seismic activity, thermal effects, stresses related to excavation, or possibly other mechanisms. Drift collapse could affect stability of the engineered barriers and waste packages. Drift collapse may be localized as stopping at faults or other geologic features. Rockfall of small blocks may produce rubble throughout part or all of the tunnel.

Note that this FEP also encompasses FEPs ebs # 9, 11, and 37 from Table 4.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Changing stress state, either from fault (tectonic) adjustment or from seismic waves arriving from distal sources, may produce rockfall and/or ground support failure. Such displacement of surrounding rocks into the tunnels and attendant growth of the tunnel (possibly by chimneying) is categorized as tunnel failure. A distinction is made between the thermal and post-thermal states because the thermally induced compression around the drifts is expected to require higher ground accelerations in order to induce tunnel failure than for the post-thermal relaxing environment. However, such mechanical degradation or collapse of the drift is excluded from the TSPA based on low consequences. It is unlikely that drift degradation could penetrate the designed engineered barriers and impact a waste package. A detailed analysis of drift degradation is provided in E0080 (CRWMS M&O 2000h). That analysis provides a time history of "expected" rockfall due to ongoing degradation of the drift as well due to a 10,000 year seismic event. That analysis further demonstrates that a mechanical threat to the drip shield and waste package beyond that considered in the drip shield (CRWMS M&O 2000ff) and waste package (CRWMS M&O 2000cc, CRWMS M&O 2000dd, CRWMS M&O 2000ee) design analyses does not occur. Mechanical impact on both drip shield and WPs is insufficient to cause damage so as to lead to an earlier release of radioactivity.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.07.02.01, Stability (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.02, Mechanical (events and processes in the waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.03, Rockfall stops up fault

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.04, Rockfall (rubble) (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it describes one potential mechanism for drift collapse. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.05, Mechanical failure of repository

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.06, Subsidence/collapse

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.07, Vault collapse

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.02.08, Creeping of Rock Mass

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it describes the effect of the initial excavation on repository stability. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST2, RDTME, SDS

References: E0080 (CRWMS M&O 2000h), CRWMS M&O 2000bb, CRWMS M&O 2000cc, CRWMS M&O 2000dd, CRWMS M&O 2000ee, CRWMS M&O 2000ff

6.4.32 Movement of Containers – YMP 2.1.07.03.00

FEP Description: Waste packages may move as a result of seismic activity, degradation of the invert or pedestal, rockfall, fault displacement, or other processes (See also FEP 2.1.06.05.00 - Degradation of Invert and Pedestal.)

Note that this FEP also encompasses FEP ebs # 3 from Table 4.

Screening Decision and Regulatory Basis: Included (WP contacting invert effect on radionuclide transport), Excluded – Low Consequence (WP causing drip shield separation)

Screening Argument: Movement of the waste packages is potentially important because it could result in damage to the waste package as a result of falling onto the invert, accelerated corrosion of the waste package at high-stress contact points with the invert, and enhanced corrosion of the waste package if direct contact with the invert provides an additional source of water. These effects, dealing directly with waste package damage mechanisms, are discussed in the waste package and drip shield FEPs AMR (CRWMS M&O 2000w) and are not considered here. An additional aspect of this FEP involves movement of the waste packages against the drip shield, potentially resulting in drip shield separation. This phenomenon is explicitly considered in the abstraction for drip shield separation (as documented in E0095 (CRWMS M&O 2000j)), which screens out container movement against the drip shield as a significant contributor to drip shield separation. It is argued therein that the consequences of contact between waste package and drip shield from pedestal failure are accounted for in the large uncertainty that is considered in the seismic displacement model for the drip shield. Thus, this aspect of the FEP is excluded on the basis of low consequences.

TSPA Disposition: The other aspect of this FEP involves the effect of waste package contact with the invert on radionuclide transport. As discussed for FEP 2.1.06.05.00 (Degradation of Invert and Pedestal), this aspect of the FEP is included. The radionuclide transport abstraction for the EBS (as documented in E0095 (CRWMS M&O 2000j)) conservatively ignores the pedestal and assumes that the waste package is in direct contact with the invert at all times. Thus, no impediment to radionuclide transport associated with diffusion along a wet pedestal surface is accounted for.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.07.03.01, Movement of canister in buffer/backfill

Relationship to Primary FEP: This FEP is a subset of the Primary FEP that deals with the issue of canister movement in buffer/backfill. Since there is no buffer/backfill used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.07.03.02, Canister or container movement

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.03.03, Movement of canister in buffer/backfill

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.07.03.01, but retained in the FEP list for completeness.

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.07.03.04, Canister sinking

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the issue of canister sinking in bentonite. Since there is no bentonite used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: CLST1, CLST2, RDTME, SDS

References: E0095 (CRWMS M&O 2000j)

6.4.33 Hydrostatic Pressure on Container – YMP 2.1.07.04.00

FEP Description: Waste packages emplaced in the saturated zone will be subjected to hydrostatic pressure in addition to stresses associated with the evolution of the waste and barrier system.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: A repository at Yucca Mountain locates waste above the water table in a fractured, porous medium. Thus, the pressure is approximately atmospheric. Consequently, this

FEP is not relevant for the YMP design, which calls for emplacement in the unsaturated zone, and there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.07.04.01, Excessive hydrostatic pressures (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.04.02, Changed hydrostatic pressure on canister

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST2

References: None

6.4.34 Creeping of Metallic Materials in the EBS – YMP 2.1.07.05.00

FEP Description: Metals used in the waste package or drip shield may deform by creep processes in response to deviatoric stress.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: For the drip shield, the only source of a deviatoric stress that could lead to creep is rock fall. For the WPs, deviatoric stress could result both from rock fall, as well as from internal pressurization of the WPs. For rock fall, both the drip shield and WP have been designed to survive this threat. Internal pressurization of the WP is not expected to be a significant threat both because of the lack of a significant internal pressure source, as well as because of the relatively low WP temperature. Thus, the timing of failure of both drip shield and WP would simply be governed by that determined from corrosion considerations. While this FEP is relevant from an EBS perspective in that the EBS analysis must determine appropriate thermal conditions, the actual response of the drip shield and WP to such deviatoric stresses is a WP issue. As such, this FEP is discussed in more detail in the AMR dealing with WP and drip shield degradation FEPs (CRWMS M&O 2000w).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequence to the calculated dose.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.07.05.01, Creeping of copper

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the issue of copper creeping. Since there are no copper canisters used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.07.05.02, External stress (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.07.05.03, Voids in the lead filling

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the impact of voids in the lead filling on canister creep. Since there is no lead filling used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.07.05.04, Loss of ductility (of waste container)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with loss of ductility of the copper canister material. Since there are no copper canisters used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.07.05.05, Incomplete filling of containers

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with incomplete filling of containers with glass bead particulate. Since there is no glass bead particulate used in the design baseline (CRWMS M&O 2000bb) at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: CLST2

References: CRWMS M&O 2000y, CRWMS M&O 2000b

6.4.35 Floor Buckling – YMP 2.1.07.06.00

FEP Description: Buckling, or heave, of the drift floor occurs in response to changing stress. Floor buckling may affect the performance of components of the EBS such as the drip shield, the invert, and the pedestal. Effects may include movement of EBS components, and changes in the topography of the surface of the drift floor and invert that may affect water flow.

Note that this FEP also encompasses FEP ebs # 35 from Table 4.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: The effect of floor heave and buckling on drip shield response has been screened out of the TSPA because of low consequence. Arguments documented in E0095 (CRWMS M&O 2000j) demonstrated that the vertical displacement of the floor due to in situ stress and thermal response will be on the order of 10 mm. This displacement will produce only minor shifting in the drip shields and will not compromise their integrity because the overlap between adjacent drip shields is much larger, between 200 mm and 600 mm. The effect of floor heave on position of the waste packages is also minor. A displacement of 10 millimeters at one end of a 5000 millimeter long package results in an angle of inclination of less than one degree. The impacts of floor heave and buckling have therefore been screened out of the TSPA.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.07.06.01, Basin formation (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with basin formation following floor buckling. Because the magnitude of floor buckling is shown to be small relative to the depth of the invert, such basin formation would not impact the waste containers.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: RDTME3

References: E0095 (CRWMS M&O 2000j)

6.4.36 Increased Unsaturated Water Flux at the Repository – YMP 2.1.08.01.00

FEP Description: An increase in the unsaturated water flux at the repository affects thermal, hydrological, chemical, and mechanical behavior of the system. Extremely rapid influx could reduce temperatures below the boiling point during part or all of the thermal period. Increases in flux could result from climate change, but the cause of the increase is not an essential part of the FEP.

Screening Decision and Regulatory Basis: Included

Screening Argument: Climate is expected to change. As a surrogate for that change, three climate states with different infiltration fluxes have been considered in TSPA modeling

TSPA Disposition: This is implicitly included in the EBS modeling through the water influx time histories as provided from the NFE analysis (CRWMS M&O 2000t).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

> **FEP Number and Name: 2.1.08.01.01, Waste container is thermally quenched by rapid influx of water**
>
> Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.
>
> Screening and Disposition: Same as the Primary FEP.

IRSR Issues: None for EBS

References: CRWMS M&O 2000t

6.4.37 Enhanced Influx (Philip's Drip) – YMP 2.1.08.02.00

FEP Description: An opening in unsaturated rock alters the hydraulic potential, affecting local saturation around the opening and redirecting flow. Some of the flow is directed to the opening where it is available to seep into the opening.

Screening Decision and Regulatory Basis: Included

Screening Argument: This FEP is included in the TSPA as discussed in the TSPA disposition.

TSPA Disposition: Philip's drip (Philip et al. 1989) refers to water entry into a tunnel (drip) from downward unsaturated seepage in the surrounding host rock. Since the Yucca Mountain tunnels will be located in the UZ, this phenomenon governs water ingress into the tunnel and is included in the seepage flux model for TSPA (CRWMS M&O 2000n, CRWMS M&O 2000t). This is also discussed in the FEPs AMR for the NFE (CRWMS M&O 2000r).

IRSR Issues: ENFE1, TEF1, TEF2

References: Philip et al. 1989, CRWMS M&O 2000n, CRWMS M&O 2000t

6.4.38 Cold Traps – YMP 2.1.08.04.00

FEP Description: Emplacement of waste in drifts creates thermal gradients within the repository. Such thermal gradients can lead to drift-scale and repository-scale cold traps characterized by latent heat transfer from warmer to cooler locations. This mechanism can result in condensation forming on the roof of the drifts or elsewhere in the EBS, leading to enhanced dripping on the drip shields, waste packages, or exposed waste material.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Drift-scale cold traps are those defined to occur due to localized thermal gradients within the tunnel, as for example between the hot waste package and the tunnel wall. The possibility of condensation forming on the backs of drifts due to radial thermal gradients (WP to drift wall) is included in the thermal/hydrologic calculations of emplacement drift response, as documented in E0120 (CRWMS M&O 2000m). This is similar to the possibility of condensation forming on the underside of the drip shield due to evaporation from the invert (see primary FEP 2.1.08.14.00). An evaluation of such condensation is documented in E0090 (CRWMS M&O 2000i), where it is shown that such condensation would not occur. Thus, while such condensation pathways exist in the TSPA supporting models, no condensation is actually calculated. Thus, such condensation is excluded from TSPA based on low consequence to dose. Repository-scale cold traps are those defined to occur along the length of the drift, between regions of warmer and cooler waste packages. This could be between the repository center and the cooler edges or between other regions with varying temperatures. At the present time, this aspect of the FEP is excluded because it is not expected to have a significant consequence on the calculated dose. There are several reasons for this. First, the effect would be localized to only those regions with cooler temperature. Second, the magnitude of the extra dripping is expected to be small relative to that already calculated. Third, the total water flux out of the EBS would be largely unimpacted (simply shifted from one location in the drift to another). Thus, any adverse impacts in the cooler locations, would be partially offset by the beneficial impact of reduced dripping in the hotter regions. On this basis, cold traps are currently excluded based on low-consequence to dose.

TSPA Disposition: Enhanced flow due to cold traps is excluded from the TSPA on the basis of low consequence to the expected source term as discussed above.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.08.04.01, Condensation Forms on Backs of Drifts

Relationship to Primary FEP: This FEP is a subset of the primary FEP dealing with drift-scale cold traps. As summarized in the primary FEP discussion, this FEP is explicitly considered in the TSPA.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE4, TEF1, TEF2

References: E0095 (CRWMS M&O 2000j), E0120 (CRWMS M&O 2000m)

6.4.39 Flow Through Invert – YMP 2.1.08.05.00

FEP Description: The invert, a porous material consisting of crushed tuff, separates the waste package from the bottom of the tunnel (boundary to the UZ).

Screening Decision and Regulatory Basis: Included

Screening Argument: Flow of seepage water and associated radionuclides, as applicable, through the invert must be modeled to characterize the source term for the UZ.

TSPA Disposition: Advective and diffusive flow through the invert are included in the EBS radionuclide transport abstraction for TSPA, E0095 (CRWMS M&O 2000j). No credit for sorption or colloid filtration is included; a conservative modeling simplification.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.08.05.01, Fracture flow through the invert

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (flow through fractures), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.05.02, UZ flow through/around the collapsed invert

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (flow through matrix), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE4

References: E0095 (CRWMS M&O 2000j)

6.4.40 Wicking in Waste and EBS – YMP 2.1.08.06.00

FEP Description: Capillary rise, or wicking, is a potential mechanism for water to move through the waste and engineered barrier system.

Screening Decision and Regulatory Basis: Included

Screening Argument: Wicking is a water transport mechanism that must be accounted for in the TSPA.

TSPA Disposition: Wicking in the invert is included in the calculated thermal/hydrologic response of the emplacement drift and surrounding host rock as documented in E0120 (CRWMS M&O 2000m). This wicking flux is included in calculating the fluid influx into the EBS as documented in E0095 (CRWMS M&O 2000j). Should backfill be included in the repository design, wicking in the backfill would also be considered. Within the WP, the effects of wicking are automatically accounted for because the material inside the WP is modeled as a single mixing cell (CRWMS M&O 2000j). Thus, the rate of flow and radionuclide is bounded by this treatment.

IRSR Issues: ENFE1, ENFE2, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), E0120 (CRWMS M&O 2000m)

6.4.41 Pathways for Unsaturated Flow and Transport in the Waste and EBS – YMP 2.1.08.07.00

FEP Description: Unsaturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.

Screening Decision and Regulatory Basis: Included

Screening Argument: The details of the internal pathways providing release from a container and the ex-container pathways for transport within the EBS are both modeled conservatively in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j).

TSPA Disposition: The current EBS TSPA model uses conservative assumptions to bound the impact of potential pathways on flow and transport. First, the waste form and waste package are represented as a single mixing cell. Within this mixing cell, any water that has been calculated to enter the cell instantaneously equilibrates chemically with the waste form. No flow resistance into or out of the mixing cell is considered, so that diffusive and/or advective transport of radionuclides into the EBS is maximized. Ex-container transport pathways within the EBS are also modeled conservatively. Because the invert is a minor barrier to flow and transport in comparison to the waste package, the drip shield, and the UZ beneath the drift, diffusive and advective transport of radionuclides through the invert is modeled by ignoring the possibly beneficial effects of sorption and colloid filtration. A detailed discussion of the treatment of the diffusive and advective transport pathways within the waste and the EBS is provided in the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.08.07.01, Residual canister (crack/hole effects)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the effect of partially intact canisters on water contacting the WF. This is considered in a very conservative way by limiting the surface area through which water can flow into the WP.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.07.02, Properties of failed canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the long-term degradation of the WP after initial failure. While the FEP is written for a copper/steel canister design, the general issue is relevant for any WP design. Long-term degradation of the WPs at Yucca Mountain is an integral part of the modeling of WP degradation. The resulting time-dependent degradation profile is then used in calculating water influx into the WP.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.07.03, Container-partial corrosion

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.08.07.01, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.07.04, Hydraulic conductivity (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the impact of buffer/backfill on flow. Because no buffer/backfill is used as part of the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.08.07.05, Consolidation of waste

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the impact of salt creep on flow. Because the Yucca Mountain repository design baseline does not include locating the repository in a salt formation, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.08.07.06, Channeling within the waste

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with channeling within the waste. Through the use of a simple mixing cell, the effects of such channeling are automatically accounted for in a conser vative manner.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.07.07, Unsaturated transport (water transport)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP that deals with temporary unsaturated conditions. Because the Yucca Mountain repository is located in the UZ, such conditions are automatically accounted for.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.07.08, Radionuclide transport (water transport)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and describes the modeling of radionuclide transport for another repository design. This modeling assumption, that failed canisters offer no barrier to flow and transport, is consistent with the assumptions made for Yucca Mountain.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j)

6.4.42 Induced Hydrological Changes in the Waste and EBS – YMP 2.1.08.08.00

FEP Description: Thermal, chemical, and mechanical processes related to the construction of the repository and the emplacement of waste may induce changes in the hydrological behavior of the system.

Note that this FEP also encompasses FEPs ebs # 13 and 14 from Table 4.

Screening Decision and Regulatory Basis: Included

Screening Argument: The hydrological behavior of the repository is influenced by the presence of the emplacement drift and the associated waste material. This must be accounted for in the performance assessment of the repository.

TSPA Disposition: Relative to the EBS analysis, there are two ways in which induced hydrologic changes are accounted for. To the extent that the repository outside the tunnel is impacted (temperature, seepage flow, gas flow, etc.), this is accounted for in the EBS analysis through the boundary conditions provided by the NFE analysis and is not explicitly an EBS issue. Within the tunnel, the hydrological response of the EBS system is explicitly considered through the in-drift thermal-hydrologic analysis, E0120 (CRWMS M&O 2000m), taking into account the emplacement of the waste packages. This analysis is then an integral part of the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j) that feeds the TSPA.

IRSR Issues: ENFE1, ENFE4, RDTME3, TEF1, TEF2

References: E0095 (CRWMS M&O 2000j), E0120 (CRWMS M&O 2000m)

6.4.43 Saturated Groundwater Flow in Waste and EBS – YMP 2.1.08.09.00

FEP Description: Saturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Saturated flow pathways in the waste are screened out because the failed canister is conservatively assumed to provide no resistance to flow. An analysis of an alternate flow and transport scenario, in which saturated conditions were created within a partially intact waste package (the bathtub effect), were shown to result in lower early releases (CRWMS M&O 2000j). Thus, such saturated pathways were excluded from the TSPA on the basis of negligible consequences to expected dose (bounded by current modeling approach).

Saturated flow pathways in the quartz (if backfill were to be included in the repository design) would be minimized and potentially screened out because wicking, driven by capillary forces, would distribute seepage uniformly throughout the drifts. Finally, saturated flow pathways in the invert are ignored, because the invert will offer little or no resistance to flow and free drainage conditions are likely to be maintained (CRWMS M&O 2000i). The saturation level within the invert is calculated in the TSPA, and this in turn is used to calculate the radionuclide diffusion to the NFE when the drip shield is intact (CRWMS M&O 2000j). No preferential pathways within the invert that would result in saturated flow have been identified. Thus, this FEP is excluded from the TSPA based on low consequences to the expected dose. It should also be noted that the exclusion of this FEP is conservative in that no credit is taken for the increased residence time that would be required for the development of saturated pathways.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence (and the fact that it's exclusion is conservative).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.08.09.01, Hydraulic head (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with flow in a saturated repository. Because the emplacement drift is located in the UZ for the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.08.09.02, Cavitation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with flow in a saturated repository. Because the emplacement drift is located in the UZ for the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE1, ENFE4

References: E0095 (CRWMS M&O 2000j), E0090 (CRWMS M&O 2000i)

6.4.44 Resaturation of Repository – YMP 2.1.08.11.00

FEP Description: Water content in the repository will increase following the peak thermal period.

Screening Decision and Regulatory Basis: Included

Screening Argument: The time-dependent water content in the repository is a key parameter that affects corrosion processes as well as waste form degradation.

TSPA Disposition: The seepage influx and the capillary influx to the EBS are calculated as part of the NFE analysis as documented in E0130 (CRWMS M&O 2000n). This analysis calculates the coupled thermal/hydraulic response of the emplacement drifts and EBS and provides this as input to the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.08.11.01, Reflooding (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness. While saturation of the repository will not occur (location in UZ), the time dependent influx of water is explicitly accounted for.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.08.11.02, Brine inflow (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion. Note that while the specific words are pertinent only to WIPP, the general concept applies equally to Yucca Mountain.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, TEF1, TEF2

References: E0095 (CRWMS M&O 2000j), E0130 (CRWMS M&O 2000n)

6.4.45 Drainage with Transport – Sealing and Plugging – YMP 2.1.08.12.00

FEP Description: Normal functioning of drainage in the drifts is not established, so how drainage will change if fractures are plugged is unclear. Suggestions include ponding until fractures in the wall are reached by the water level or until there is sufficient head to clear the fractures.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Transport of contaminants to the drift floor could result in a layer of sediment on the floor or in blockage of the fractures in the floor. This combined with floor buckling could result in localized regions of water accumulation. However, the extent of such ponding is expected to be very small. This is discussed in the summary for this FEP in Attachment A. Further, the waste packages would still sit above the buckled floor (on the invert), and thus would not be immersed in water even if some ponding occured. Thus, the fraction of waste packages in continuous contact with water would be negligible and the effect on radionuclide release and hence dose is expected to be negligible.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

IRSR Issues: None

References: (CRWMS M&O 2000j)

6.4.46 Drains – YMP 2.1.08.13.00

FEP Description: Water accumulation in the drift would wet the invert materials, possibly pond, and provide a continuing source of water vapor beneath the drip shield and backfill for interaction with waste packages and their supports. Engineered drains are a consideration for mitigating such water accumulation and ponding.

Screening Decision and Regulatory Basis: Excluded - Low Probability (not credible)

Screening Argument: Drains are not part of the baseline design (CRWMS M&O 2000bb). Thus there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low probability (not credible).

IRSR Issues: None

References: (CRWMS M&O 2000bb)

6.4.47 Condensation on Underside of Drip Shield – YMP 2.1.08.14.00

FEP Description: Condensation of water on the underside of drip shield affects waste package hydrologic and chemical environment.

Screening Decision and Regulatory Basis: Excluded – Low Consequence

Screening Argument: Condensation of water on the underside of the drip shield may occur if the temperature of this surface is sufficiently low relative to the invert. In that case, water may drip onto the WP prior to drip shield failure, potentially resulting in more rapid WP corrosion than what would be expected simply under humid conditions and earlier release of fission products. The possibility of such condensation forming on the drip shield is included in the thermal/hydrologic calculations of emplacement drift response, as documented in E0120 (CRWMS M&O 2000m). An evaluation of such condensation is documented in E0090 (CRWMS M&O 2000i), where it is shown that the drip shield surface is too hot for condensation to occur. As a result, the quantity of any such condensation and resulting dripping is negligible, and the timing of WP failure is expected to be unchanged. Thus, while such condensation pathways exist in the TSPA supporting models, no condensation is actually calculated. For these reasons, such condensation is excluded from TSPA based on low consequence to dose.

Note that this FEP also encompasses FEP ebs #15 from Table 4, and is related to FEP 2.1.06.06.00.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

IRSR Issues: None

References: (CRWMS M&O 2000m)

6.4.48 Properties of the Potential Carrier Plume in the Waste and EBS – YMP 2.1.09.01.00

FEP Description: When unsaturated flow in the drifts is re-established following the peak thermal period, water will have chemical and physical characteristics influenced by the near field host rock and EBS. Water chemistry may be strongly affected by interactions with cementitious materials.

Screening Decision and Regulatory Basis: Included (all aspects of the FEP other than those explicitly excluded), Excluded – Low Consequence (effect of cementitious leachate and corrosion products)

Screening Argument: The chemical and other properties of the infiltrate entering the emplacement drifts are determined as part of the NFE analysis (CRWMS M&O 2000n), accounting for the thermal/hydrologic/chemical effects of the host rock. Within the emplacement drift, the chemistry of the seepage is calculated as part of the EBS physical and chemical environment model (CRWMS M&O 2000k). This is primarily governed by the seepage/invert interactions submodel (CRWMS M&O 2000b). Two potentially important sources of material that could impact this carrier plume are the cementitious material around the rock bolts and the corrosion products formed within the EBS (see FEP 2.1.09.02.00). The effects of the degradation of cementitious material in the drift-stabilization structures are explicitly analyzed in the EBS physical and chemical environment analysis documented in E0100 (CRWMS M&O 2000k). This analysis includes both leaching of the cement around the rock bolts and subsequent equilibration of the leachate with gas-phase CO_2 in the drift environment. Results of this analysis show that the neutralization of the leachate will be very rapid, such that the leachate composition will be similar to the seepage waters by the time the leachate reaches the drip shield. In addition, the total quantity of such leachate is very small because of the small quantity of cement used in the drift stabilization structures. For this reason, this FEP may be excluded on the basis of low consequence.

TSPA Disposition: The chemical and other properties of the infiltrate entering the emplacement drifts are determined as part of the NFE analysis (CRWMS M&O 2000n), accounting for the thermal/hydrologic/chemical effects of the host rock. This aspect of the FEP is discussed in the NFE FEPs AMR (CRWMS M&O 2000r). Within the emplacement drift, the chemistry of the seepage is calculated as part of the EBS physical and chemical environment model (CRWMS M&O 2000k). This is primarily governed by the seepage/invert interactions submodel (CRWMS M&O 2000b). Thus, aside from the effects of cementious material leachate (screened out above) and corrosion products (see FEP 2.1.09.02), this FEP is included in the EBS modeling for TSPA.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.01.01, Reactions with cement pore water

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals with the effect of cementitious materials on water chemistry. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.02, Reactions with cement pore water

Relationship to Primary FEP: This FEP is completely redundant with FEP 2.1.09.01.01, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.03, Induced chemical changes (in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.04, Interactions of host materials and ground water with repository material

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.05, TRU silos cementitious plume

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the cementitious material in the TRU silos for another repository design. Because such cementitous material is not used in the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.01.06, Water chemistry, canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the chemistry of the water between inner and outer WP canisters for another repository design. Because such a steel/copper WP design is not used in the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.01.07, Transport of chemically-active substances into the near-field

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (dealing with the chemistry of the water entering the NFE), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.08, Incomplete near-field chemical conditioning

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the cementitious material in the WPs themselves for another repository design. Because such cementitous WP materials are not used in the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.01.09, Chemical processes (in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.10, Hyperalkaline carrier plume forms

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the impact of a cementitious liner on groundwater chemistry. Because such a liner is not part of the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.01.11, Chemical interactions (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.12, TRU alkaline or organic plume

Relationship to Primary FEP: This FEP is partially redundant with secondary FEP 2.1.09.01.05. In addition, it deals with the issue of organic waste in the WIPP waste stream. Because such cementitous material and organic waste is not relevant to the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.01.13, Interactions of waste and repository materials with host materials

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.01.14, TRU alkaline or organic plume

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.09.01.12, but retained in the FEP list for completeness.

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE2, ENFE3, RT1

References: E0095 (CRWMS M&O 2000j), E0010 (CRWMS M&O 2000b)

6.4.49 Interaction with Corrosion Products – YMP 2.1.09.02.00

FEP Description: Corrosion products produced during degradation of the metallic portions of the EBS and waste package may affect the mobility of radionuclides. Sorption/desorption and coprecipitation/dissolution processes may occur.

Note that this FEP also encompasses FEP ebs # 7 from Table 4.

Screening Decision and Regulatory Basis: Included (Colloids), Excluded – Low Consequence (Effects other than colloids)

Screening Argument: Interaction of contaminants with corrosion products (from the breached waste package or its remnants, from the pedestal, from rock reinforcement materials, etc.) may control mobilization and speciation of the contaminants (e.g., Fe oxyhydroxides and colloids). The effects of these corrosion products on seepage water chemistry are analyzed in the *EBS Physical and Chemical Environmental Model* AMR, E0100 (CRWMS M&O 2000k) and its abstraction AMR, E0010 (CRWMS M&O 2000b). These analyses show that the effect of these corrosion products on water chemistry can be excluded. Corrosion products can also potentially sorb radionuclides and retard transport. However, these features are conservatively ignored in the TSPA model. The effects of the corrosion products on the in-package chemistry are not an EBS issue and are discussed in the miscellaneous waste form FEPs AMR (CRWMS M&O 2000q).

TSPA Disposition: Corrosion products can also serve as a source for colloids for radionuclide transport. As discussed under FEP 2.1.09.17.00 (corrosion product colloids), this is included in the TSPA as a contributor to transport. All other aspects of this FEP are excluded based on low consequence to dose.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.02.01, Interactions with corrosion products and waste

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.02.02, Effects of metal corrosion (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals only with the impact of corrosion products on the water chemistry in the drift. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.02.03, Container corrosion products

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it only deals with corrosion products from the containers. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.02.04, Chemical buffering (canister corrosion products)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals with the impact of corrosion products from the canister on water chemistry in the drift. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.02.05, Radionuclide sorption and co-precipitation (in EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals with the impact of corrosion products on radionuclide sorption. Sorption as a phenomenon is dealt with explicitly in FEP 2.1.09.05.00. It is demonstrated therein that excluding sorption is conservative.

Screening and Disposition: Excluded on the basis of low consequence (and conservatism).

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), E0010 (CRWMS M&O 2000b), F0170 (CRWMS M&O 2000p)

6.4.50 In-drift Sorption – YMP 2.1.09.05.00

FEP Description: Sorption of radionuclides within the waste and EBS may affect the aqueous concentrations.

Screening Decision and Regulatory Basis: Excluded - Low Consequence (Favorable consequences are neglected by excluding this FEP)

Screening Argument: Sorption of radionuclides on other materials within the EBS would serve to delay release to the environment. Thus, it is conservative from a consequences perspective to ignore this effect, and the exclusion of this FEP has a negligible impact on adverse dose consequences.

TSPA Disposition: As a bounding estimation, sorption of fission products within the EBS, which would act to delay release, is conservatively ignored.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.05.01, Selective sorption of Pu from solution

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals strictly with the issue of Pu sorption. This FEP is covered by the screening argument discussion for the primary.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.05.02, Sorption

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.05.03, Radionuclide retardation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the effect of a bentonite buffer. Because bentonite is not used as part of the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.05.04, Sorption on filling materials

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE4, RT1

References: E0095 (CRWMS M&O 2000j)

6.4.51 Reduction-oxidation Potential in Waste and EBS – YMP 2.1.09.06.00

FEP Description: The redox potential in the waste and EBS influences the oxidation of barrier and waste-form materials and the solubility of radionuclide species. Local variations in the redox potential can occur.

Screening Decision and Regulatory Basis: Included

Screening Argument: The redox potential in the groundwater is taken into account in the calculations that examine the probable range of EBS fluid chemistries.

TSPA Disposition: The influence of the redox potential on waste form degradation is not an EBS issue, but is addressed in the miscellaneous waste form FEPs AMR (CRWMS M&O 2000q).

The redox potential is an issue for the ENS modeling relative to its impact on the water chemistry for waste package and drip shield corrosion, and its impact on radionuclide solubility for transport through the invert. Implicit in the modeling of the EBS water chemistry is the assumption that atmospheric gases are in equilibrium with the solutions in the EBS and will remain in equilibrium throughout any chemical reaction (see FEP 2.1.09.07.00). Because of the location of the repository in the UZ, oxidizing conditions are calculated for all EBS geochemical modeling supporting the TSPA. Even though oxygen fugacity will change within the EBS with time due to such processes as structural material (WP, drip shield, rails, etc.) corrosion, there is ample oxygen available to oxidize all such materials. Effects from the associated changes in the oxygen fugacity will not significantly change concentrations of potential redox species in solution, which could be derived from iron and similar redox-sensitive materials (CRWMS M&O 2000k).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.06.01, Redox front (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.06.02, Reduction-oxidation fronts (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.06.03, Localized reducing zones (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.06.04, Redox front (in buffer/backfill)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the effect of buffer/backfill. Because buffer/backfill is not used as part of the design baseline at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.06.05, Fe control of oxidation state of contaminants

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals with metal corrosion on the oxidation state of the contaminants. Metal corrosion and the associated corrosion products are explicitly considered in the groundwater chemistry discussion for FEP 2.1.09.02.00.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), F0170 (CRWMS M&O 2000p)

6.4.52 Reaction Kinetics in Waste and EBS – YMP 2.1.09.07.00

FEP Description: Chemical reactions, such as radionuclide dissolution/precipitation reactions and reactions controlling the reduction-oxidation state, may not be equilibrium in the drift and waste environment.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Effects of kinetics on waste-form dissolution reactions are considered in the in-package chemistry abstraction documented in F0170 (CRWMS M&O 2000p) supporting E0010 (CRWMS M&O 2000b) and discussed in the miscellaneous waste-form FEPs AMR (CRWMS M&O 2000q). Relative to the EBS modeling, reaction kinetics may impact the water chemistry, the rate of mineral precipitation and resolution, and the reduction-oxidation state of the EBS environment. These effects are important if they impact corrosion/failure of the drip shield and waste package, or if they impact radionuclide transport. For the environment relevant to Yucca Mountain, the water chemistry is dominated by the concentration of dissolved salts, such as calcite (a determining factor for ph), and the partial pressure of oxygen and carbon dioxide. Reactions involving such mineral salts are very rapid relative to the transport time frame within the EBS. The EBS physical and chemical environment model (CRWMS M&) 2000k) shows that the use of equilibrium chemistry based on these and other considerations is a valid approximation. Thus, reaction kinetics within the EBS can be excluded based on low consequence to dose.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.07.01, Reaction kinetics (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness. Note that it deals explicitly with the issue of reduced waste form dissolution rates, an effect that is conservatively ignored.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), F0170 (CRWMS M&O 2000p)

6.4.53 Chemical Gradients/Enhanced Diffusion in Waste and EBS – YMP 2.1.09.08.00

FEP Description: The existence of chemical gradients within the disposal system, induced naturally or resulting from repository material and waste emplacement, may influence the transport of contaminants of dissolved and colloidal species. This could include, for example, diffusion in and through failed canisters.

Screening Decision and Regulatory Basis: Included (diffusion out of the failed WPs and through the invert), Excluded - Low Consequence (diffusion within the WF)

Screening Argument: Chemical heterogeneity in the waste and EBS means that there are persistent chemical gradients that could influence transport. At the present time, the WF is represented by a single mixing cell (CRWMS M&O 2000j), which conservatively assumes instantaneous chemical equilibrium. For this conservative modeling of the WF, chemical gradients and enhanced diffusion will have no adverse impact on WF performance relative to that already calculated. Thus, the effect of chemical gradients on these processes is excluded on the basis of low (adverse) consequence to dose.

TSPA Disposition: For radionuclide transport out of the failed WP and through the invert into the NFE, diffusion represents the dominant transport mechanism in the absence of large advective flows. Gradients that would disperse radionuclides along transport pathways are conservatively ignored. Gradients that would hasten transport out of the failed WP and through the EBS are explicitly included in the radionuclide transport abstraction (CRWMS M&O 2000j).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.08.01, Enhanced diffusion (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.08.02, Chemical gradients (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.08.03, Diffusion in and through failed canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0095(CRWMS M&O 2000j), E0010 (CRWMS M&O 2000b)

6.4.54 Waste-Rock Contact – YMP 2.1.09.11.00

FEP Description: Waste and rock are placed in contact by mechanical failure of the drip shields and waste packages. Reactions between uranium, rock minerals, and water, in contact with both, precipitate uranium, leading spent fuel to dissolve more rapidly than if constrained by the equilibrium solubility of uranium.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Waste and rock could come in contact by mechanical failure of the drip shields and waste packages. Reactions between uranium, rock minerals, and water, in contact with both, could precipitate uranium, leading spent fuel to dissolve more rapidly than if constrained by the equilibrium solubility of waste-form uranium phases. To the extent that such enhanced dissolution could occur, this is a waste form degradation issue and not modeled explicitly in the EBS analysis.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

IRSR Issues: ENFE3

References: E0010 (CRWMS M&O 2000b)

6.4.55 Rind (Altered Zone) Formation in Waste, EBS, and Adjacent Rock – YMP 2.1.09.12.00

FEP Description: Thermo-chemical processes involving precipitation, condensation, and redissolution alter the properties of the waste, EBS, and the adjacent rock. These alterations may form a rind, or altered zone, in the rock, with hydrological, thermal, and mineralogical properties different from the current conditions.

Screening Decision and Regulatory Basis: Excluded – Low Consequence (for EBS components)

Screening Argument: The idea of an altered zone, or rind, as described in the FEP description may apply to the waste form, components within the EBS, and the host rock bordering the emplacement drift. For the waste form, this issue is dealt with in the miscellaneous waste form FEPs AMR (CRWMS M&O 2000q). For the changes in the hydrologic properties of the host rock, this effect is dealt with in the NFE FEPs AMR (CRWMS M&O 2000r). In both cases, if there were effects attributable to such a rind, it would be incorporated in the boundary conditions supplied to the EBS analysis. For components within the EBS, one can conceive of a rind forming on metal surfaces as a result of water evaporation and precipitation of dissolved minerals, possibly in the form of scale. The chemical environment on the surfaces of the drip shield and waste package as a result of water condensation and evaporation is accounted for in the evaluation of failure for these components (CRWMS M&O 2000x). The potentially beneficial effects of such a rind forming a protective coating that inhibits corrosion is conservatively ignored.

TSPA Disposition: For purposes of EBS modeling, this FEP is excluded on the basis of low consequence to dose.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.12.01, Deep alteration of the porosity of drift walls

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, TEF1, TEF2

References: E0100 (CRWMS M&O 2000k)

6.4.56 Complexation by Organics in Waste and EBS – YMP 2.1.09.13.00

FEP Description: The presence of organic complexants in water in the waste and EBS could augment radionuclide transport by providing a transport mechanism in addition to simple diffusion and advection of dissolved material. Organic complexants may include materials found in natural groundwater such as humates and fulvates, or materials introduced with the waste or engineered materials.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Complexation of radionuclides with organic species has been excluded from the TSPA on the basis of negligible consequences for two reasons. First, this mechanism would be most significant if it could alter the form of the dissolved radionuclides thereby reducing the likelihood of sorption in the invert. However, since sorption, in the WF and EBS, is presently ignored in the TSPA (see FEP 2.1.09.05.00), the transport of radionuclides is already maximized, and the neglect of complexation has no impact on the calculated release rate. Second, complexation in the immediate vicinity of the waste form could increase the rate of radionuclide release if the release rate is solubility limited. However, the low concentration of organics in the Yucca Mountain repository makes this effect negligible (CRWMS M&O 2000d).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.13.01, Methylation (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (formation of methylated species), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.02, Humic and fulvic acids

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (although it also includes a discussion of waste forms not relevant to Yucca Mountain), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.03, Complexation by organics

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.04, Fulvic acid

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (concerning fulvates), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.05, Humic acid

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (concerning humates), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.06, Complexing agents

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.07, Organics (complexing agents)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the impact of organics on reducing sorption. While it is in a sense a subset of the primary FEP, it is also not relevant because no credit for sorption is taken in the analysis.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.08, Organics (complexing agents)

Relationship to Primary FEP: This FEP is completely redundant with secondary FEP 2.1.09.13.07, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.09, Organic complexation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with the enhancement of radionuclide transport due the formation of aqueous complexes, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.10, Organic ligands

Relationship to Primary FEP: This FEP is completely redundant with secondary FEP 2.1.09.13.02 (even though it has a different title), but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.11, Kinetics of organic complexation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (dealing with formation kinetics), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.13.12, Introduced complexing agents

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion. This FEP is also related to primary FEP 1.1.02.03.00, undesirable materials left.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000d)

6.4.57 Colloid Formation in Waste and EBS – YMP 2.1.09.14.00

FEP Description: Colloids in the waste and EBS may affect radionuclide transport. Different types of colloids may exist initially or may form during the evolution of the system by a variety of mechanisms. This FEP aggregates all types of colloids into a single category. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening Decision and Regulatory Basis: Included

Screening Argument: See separate discussion under FEPs 2.1.09.15.00, 2.1.09.16.00, 2.1.09.17.00, and 2.1.09.18.00.

TSPA Disposition: See separate discussion under FEPs 2.1.09.15.00, 2.1.09.16.00, 2.1.09.17.00, and 2.1.09.18.00.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.14.01, Colloid generation-source term (in waste and EBS)

Relationship to Primary FEP: This FEP deals with colloids associated with bentonite buffer/backfill. Since there is no bentonite buffer/backfill used in the design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.09.14.02, Agglomeration of Pu colloids

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.03, Colloids (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.04, Colloids/particles in canister

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.05, Colloid formation

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.06, Colloids

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.07, Colloids, complexing agents

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.08, Colloid generation and transport

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP

2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.09, Colloid formation, dissolution and transport

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.10, Colloid generation and transport

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.14.11, Colloid formation and stability

Relationship to Primary FEP: This FEP is a subset of and/or redundant with the Primary FEP. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00).

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.58 Formation of True Colloids in Waste and EBS – YMP 2.1.09.15.00

FEP Description: True colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of radionuclide-containing compounds. They may form in the waste and EBS during waste-form degradation and radionuclide transport. True colloids are also called radionuclide intrinsic colloids (or actinide intrinsic colloids, for those including actinide elements).

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: The formation of true colloids may occur as part of the waste form degradation process (as discussed in F0170 (CRWMS M&O 2000p)). Additional true colloid formation within the EBS is excluded in the TSPA on the basis of negligible consequences. This is because the EBS radionuclide transport abstraction, E0095 (CRWMS M&O 2000j) does not consider any retardation mechanisms that would cause radionuclides to precipitate out anywhere within the EBS. Thus, even if radionuclide-bearing true colloids were to form, it would not impact the radionuclide source term to the NFE as the rate of radionuclide transport is already maximized (the effect of any such colloids is already fully accounted for).

TSPA Disposition: This FEP is excluded from the TSPA (for the EBS) on the basis of negligible consequences.

IRSR Issues: ENFE3, RT1

References: E0095 (CRWMS M&O 2000j), F0170 (CRWMS M&O 2000p)

6.4.59 Formation of Pseudo-colloids (natural) in Waste and EBS – YMP 2.1.09.16.00

FEP Description: Pseudo-colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids include microbial colloids, mineral fragments, and humic and fulvic acids. This FEP addresses radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion. Pseudo-colloids formed from corrosion of the waste form and EBS are discussed in FEP 2.1.09.17.00. Microbial colloids are discussed in FEP 2.1.09.18.00.

Screening Decision and Regulatory Basis: Included

Screening Argument: Natural colloids (clay, silica, and iron oxyhydroxides) may be transported in groundwater into the repository from the vadose zone above it or may be formed from the erosion of natural backfill (if backfill were included in the repository design in the future) and invert materials (e.g., crushed tuff). Pseudo-colloids may form due to the sorption onto these natural colloids of radionuclides mobilized from degradation of the waste form. Pseudo-colloids, thus formed in the waste and EBS, may influence radionuclide transport. Analyses and field studies show that radionuclides attached to colloids may be transported long distances relative to the aqueous radionuclide.

TSPA Disposition: The impact of natural pseudo-colloids on radionuclide transport is accounted for through the determination of colloid-associated radionuclide concentration limits (CRWMS M&O 2001) the implementation of which is discussed in E0010 (CRWMS M&O 2000b).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.16.01, Pseudo colloids

<u>Relationship to Primary FEP:</u> This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.16.02, Pseudo colloids

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.09.16.01, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.16.03, Natural colloids

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.16.04, Natural colloids

Relationship to Primary FEP: This FEP is completely redundant with secondary FEP 2.1.09.16.03, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), CRWMS M&O 2001

6.4.60 Formation of Pseudo-colloids (corrosion products) in Waste and EBS – YMP 2.1.09.17.00

FEP Description: Pseudo-colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids include microbial colloids, mineral fragments, and humic and fulvic acids. This FEP addresses pseudo-colloids such as iron oxyhydroxides formed from corrosion and degradation of the metals in the waste form and EBS. Radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion are discussed in FEP 2.1.09.16.00. Microbial colloids are discussed in FEP 2.1.09.18.00.

Screening Decision and Regulatory Basis: Included

Screening Argument: Introduced materials (e.g., cement grout, carbon steel, stainless steel, aluminum, titanium-7, and Alloy-22) will be present within the WP or in the environment outside. The corrosion of these materials may produce significant quantities of colloids, primarily metal oxyhydroxides. Radionuclides will tend to sorb onto these colloids, forming pseudo-colloids. Radionuclides will also tend to sorb onto larger, immobile particles and scale, although this effect is conservatively ignored. In addition, the degradation of waste glass and spent nuclear fuel will likely produce clays (with and possibly without entrained radionuclide-bearing phases), which are another "substrate" for pseudo-colloids in the drift. Pseudo-colloids thus formed in the waste and EBS may influence radionuclide transport. Analyses and field studies show that radionuclides attached to colloids may be transported long distances relative to the aqueous radionuclide.

TSPA Disposition: The impact of pseudo-colloids (from corrosion products) on radionuclide transport is accounted for through the determination of colloid-associated radionuclide concentration limits (CRWMS M&O 2001), the implementation of which is discussed in E0010 (CRWMS M&O 2000b).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.17.01, Colloid formation is associated with container hydrolosis products

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), CRWMS M&O 2001

6.4.61 Microbial Colloid Transport in the Waste and EBS – YMP 2.1.09.18.00

FEP Description: This FEP addresses the formation and transport of microbial colloids in the waste and EBS. Pseudo-colloids formed from corrosion and degradation of the metals in the waste form and EBS are discussed in FEP 2.1.09.16.00. Radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion are discussed in FEP 2.1.09.16.00.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Microbes can affect the amount of mobile colloidal material such as clay, hematite, goethite, and silica by influencing the rate of waste package corrosion. Given the present state of knowledge, estimates of the effects of microbes on corrosion processes are highly uncertain. However, the quantities of microbes that will be available to accelerate corrosion rates are very low, as calculated in E0040 (CRWMS M&O 2000d). Also, microbial action tends to increase colloid size, which would result in increased gravitational settling and filtration. Therefore, exclusion of microbial effects from TSPA may be considered conservative. A more comprehensive discussion of such microbial colloids is presented in CRWMS M&O 2001.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of negligible consequences.

IRSR Issues: ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000d), CRWMS M&O 2001

6.4.62 Colloid Transport and Sorption in the Waste and EBS – YMP 2.1.09.19.00

FEP Description: Interactions between radionuclide-bearing colloids and the waste and EBS may result in retardation of the colloids during transport by sorption mechanisms.

Screening Decision and Regulatory Basis: Included (Transport), Excluded - Low Consequence (Sorption)

Screening Argument: The TSPA considers that all radionuclide-bearing colloids generated from waste form degradation within a failed waste package will leave the waste package and enter the drift and EBS. In reality, interactions between these radionuclide-bearing colloids and the waste and EBS would result in some retardation of the colloid transport by sorption mechanisms. However, as with in-drift sorption of dissolved radionuclides (FEP 2.1.09.05.00), this phenomenon is conservatively ignored.

TSPA Disposition: Transport of colloids through the invert by both diffusion and advection is included in the TSPA, as discussed in the EBS radionuclide transport abstraction (CRWMS M&O 2000j).. Sorption of colloids is excluded from the TSPA on the basis of low expected consequences, coupled with the fact that its exclusion is conservative.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

> **FEP Number and Name: 2.1.09.19.01, Colloid transport**
>
> Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.
>
> Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j)

6.4.63 Colloid Filtration in the Waste and EBS – YMP 2.1.09.20.00

FEP Description: Filtration processes may affect transport of radionuclide-bearing colloids in the waste and EBS.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Transport of colloids within the EBS (within the tunnel) conservatively excludes consideration of colloid filtration. In this way, the rate of transport of radionuclides into the unsaturated zone is maximized. Thus, the exclusion of this FEP has negligible consequences from a dose increase perspective and is conservatively ignored.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low expected consequences, coupled with the fact that its exclusion is conservative.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.20.01, Colloid filtration by the invert

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness. (Note that the detailed discussion of this secondary FEP considers a concrete invert, a feature not part of the current design baseline.)

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.20.02, Colloid filtration (in pores and fractures)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.20.03, Colloid filtration

Relationship to Primary FEP: This FEP is a subset of the Primary FEP in that it deals with filtration in a bentonite buffer/backfill. Since there is no bentonite in the design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0095 (CRWMS M&O 2000j)

6.4.64 Suspensions of Particles Larger than Colloids – YMP 2.1.09.21.00

FEP Description: Groundwater flow through the waste could remove radionuclide-bearing particles by a rinse mechanism. Particles of radionuclide bearing material larger than colloids could then be transported in water flowing through the waste and EBS by suspension.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Suspension of radionuclide bearing particles in groundwater flowing downward through the invert could lead to an enhanced radionuclide source term at the UZ boundary. However, it is shown in the waste form colloids abstraction (CRWMS M&O 2001) that the suspension of particles larger than colloids in the UZ and saturated zone (SZ) can be excluded on the basis of consequences. Hence, any transport of such particulate within the tunnel is irrelevant to repository performance and can be excluded on the consequences.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.09.21.01, Suspended sediment transport

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.09.21.02, Rinse

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), CRWMS M&O 2001

6.4.65 Biological Activity in Waste and EBS – YMP 2.1.10.01.00

FEP Description: Biological activity in the waste and EBS may affect disposal-system performance by altering degradation processes such as corrosion of the waste packages and waste form (including cladding), by affecting radionuclide transport through the formation of colloids and biofilms, and by generating gases.

Note that this FEP also encompasses FEP ebs # 25 from Table 4.

Screening Decision and Regulatory Basis: Included (for microbially-enhanced metal corrosion), Excluded – Low Consequence (for all EBS effects other than microbially-enhanced metal corrosion)

Screening Argument: The maximum mass of microbes is calculated in the *In-Drift Microbial Communities* AMR, E0040 (CRWMS M&O 2000d). This quantity of microbial material has been determined to be sufficiently small that its impacts on radionuclide transport (via microbial colloids) and gas generation are negligible. This is discussed in more detail under FEP 2.1.09.13.00 (complexation by organics), 2.1.09.18.00 (microbial colloid transport), and 2.1.12.04.00 (gas generation from microbial degradation). To the extent that biological activity can serve to hinder radionuclide transport through sorption, this effect has been conservatively ignored (see FEP 2.1.09.05.00). A more comprehensive discussion of this FEP for all aspects of repository performance can also be found in the WF colloids AMR (CRWMS M&O 2001). Thus, for the effects mentioned here, this FEP can be excluded on the basis of low consequence.

TSPA Disposition: An additional potential impact of microbial activity is on augmenting material corrosion. This has two consequences. First, for purposes of determining the rate of patch corrosion of the WP canister, an enhanced corrosion rate due to microbial enhancement is considered in TSPA. Thus, from a WP corrosion perspective, this FEP is included. This is discussed in more detail in the WP and drip shield degradation FEPs AMR (CRWMS M&O 2000w). Second, this enhanced corrosion rate for not only the WP, but also other EBS structural steels, can impact the seepage chemistry in the drift. Microbially enhanced corrosion of these materials leads to more rapid oxygen consumption and a lowering of the oxygen fugacity. This is accounted for in the EBS physical and environment chemical model, as documented in E0100 (CRWMS M&O 2000k), by augmenting the steel corrosion rate by a factor of 6. Thus, the impact on seepage chemistry of biological activity associated with enhanced corrosion is included in TSPA. As discussed under the Screening Argument above, all other aspects of this FEP are excluded on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.10.01.01, Microbial activity accelerates corrosion of containers

Relationship to Primary FEP: This FEP is directly relevant to WP performance and not applicable to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.02, Microbial activity accelerates corrosion of cladding

Relationship to Primary FEP: This FEP is directly relevant to WF degradation and not applicable to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.03, Microbial activity accelerates corrosion of contaminants

Relationship to Primary FEP: This FEP is directly relevant to WF degradation and not applicable to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.04, Microbes (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.05, Microorganisms (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.06, Microbial effects (in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.07, Microbial activity (in waste and EBS)

Relationship to Primary FEP: This FEP is directly relevant to WF degradation and not applicable to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.08, Microbial activity (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.09, Microbial activity (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.10, Microbial interactions

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.10.01.11, Biofilms

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion. Note that it deals explicitly with the effect of biofilms on radionuclide sorption, an effect that is conservatively ignored in the analysis

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000d), CRWMS M&O 2001

6.4.66 Heat Output/Temperature in Waste and EBS – YMP 2.1.11.01.00

FEP Description: Temperature in the waste and EBS will vary through time. Heat from radioactive decay will be the primary cause of temperature change, but other factors to be considered in determining the temperature history include the in-situ geothermal gradient, thermal properties of the rock, EBS, and waste materials, hydrological effects, and the possibility of exothermic reactions (see FEP 2.1.11.03.00). Considerations of the heat generated by radioactive decay should take different properties of different waste types, including DSNF, into account.

Screening Decision and Regulatory Basis: Included (all aspects of FEP not specifically excluded), Excluded – Low Consequence (exothermic chemical reactions)

Screening Argument: Heat generation is a major issue in repository design, particularly at Yucca Mountain, where high loading densities and high temperatures are intended to be part of the waste isolation scheme. Because of the high decay heat thermal loads, the effect of the heat generated by exothermic reactions is negligible and can be excluded on the basis of low consequences. This is specifically addressed in FEP 2.1.11.03.00, exothermic reactions.

TSPA Disposition: Relative to the performance assessment of the EBS, the temperature history is calculated explicitly as part of the *Multiscale Thermohydrologic Model*, E0120 (CRWMS M&O 2000m). This thermal history is calculated based not only on the time-dependent decay power in the waste material, but also on the ambient thermal gradient in the repository, the time-dependent water influx rate, and the thermal properties of the rock, waste, and EBS materials. The resulting thermal histories are used to determine water influx rates into the EBS (CRWMS M&O 2000pp), the likelihood of evaporation/condensation transport mechanisms within the EBS (see FEP 2.1.08.04.00 and 2.1.08.14.00), the temperature range for key chemical processes (CRWMS M&O 2000k), etc. Detailed in-package temperature histories are often not used directly in TSPA. However, they do form the basis for the design verification of those components (mechanical response of WPs to rock fall, for example). Thus, the FEP is included for all these considerations.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.01.01, Glass temperature (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the issue of waste temperature. As indicated in the screening argument for the primary, the EBS modeling provides the temperature history of the repository. The effect of this temperature on WF behavior is a WF issue and not directly relevant to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.01.02, Canister temperature

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the issue of canister temperature. As indicated in the screening argument for the primary, the EBS modeling provides the temperature history of the repository. The effect of this temperature on WP behavior is a WP issue and not directly relevant to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.01.03, Temperature, bentonite buffer

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the issue of bentonite temperature. Since no bentonite is included as part of the design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.11.01.04, Temperature, canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP that deals with the radioactive source term and the EBS properties that impact the calculated thermal response. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.01.05, Temperature, tunnel backfill

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the issue of backfill temperature. Since no backfill is included as part of the design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.11.01.06, Heat generation from waste containers

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.11.01.04, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.01.07, Radioactive decay heat

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.11.01.04, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.01.08, DOE SNF expected waste heat generation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the effect of different waste types on repository thermal response. The thermal response modeling discussed under the Primary FEP screening argument, accounts for these differences in a bounding manner.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.01.09, DOE SNF expected waste heat generation

Relationship to Primary FEP: This FEP is completely redundant with secondary FEP 2.1.11.01.09, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, TEF1, TEF2

References: E0120 (CRWMS M&O 2000m)

6.4.67 Exothermic Reactions in Waste and EBS – YMP 2.1.11.03.00

FEP Description: Exothermic reactions liberate heat and will alter the temperature of the disposal system and affect the properties of the repository and surrounding materials. Hydration of concrete used in the underground environment is an example of a possible exothermic reaction.

Screening Decision and Regulatory Basis: Excluded - Low Consequence (for EBS)

Screening Argument: Maximum rock temperatures in the drift walls are expected to reach 165-185°C (CRWMS M&O 2000m). The temperature changes suggested as a result of this FEP are inconsequential by comparison. The limited quantities of cementitious materials to be used at Yucca Mountain (grout around rock bolts) would result in insignificant heat generation relative to the decay heat source. Potentially reactive materials, such as the steel in the EBS, will degrade before WP heat output has decayed to a few percent of initial output. Thus, the magnitude of the heat generation by exothermic reactions in the EBS is negligible compared to decay heat. Thus, the temperature response is not impacted by ignoring these reactions, and the FEP can be excluded on the basis of low consequence to the expected dose. The specific issue of heat generation due to degradation of the in-package materials is dealt with in the WF FEPs AMR (CRWMS M&O 2000q).

TSPA Disposition: This FEP is excluded from the TSPA (for the EBS) on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.03.01, Concrete hydration

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (concrete hydration), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3

References: E0010 (CRWMS M&O 2000b)

6.4.68 Temperature Effects/Coupled Processes in Waste and EBS – YMP 2.1.11.04.00

FEP Description: This FEP broadly encompasses all coupled-process effects of temperature changes within the waste and EBS. Technical discussions relevant to this FEP are provided individually for each relevant process. See FEP 2.1.11.01.00 for a discussion of the temperature history of repository. See FEP 2.1.11.03.00 for a discussion of possible exothermic reactions. See FEP 2.1.11.05.00 for a discussion of the effects of differential thermal expansion of repository components. See FEP 2.1.11.07.00 for a discussion of thermally-induced stresses in the waste and EBS. See FEP 2.1.11.08.00 for a discussion of thermal effects on chemical and microbial processes. See FEP 2.1.11.09.00 for a discussion of thermal effects on fluid flow in the waste and EBS. See 2.1.11.10.00 for a discussion of the Soret effect.

Screening Decision and Regulatory Basis: Included

Screening Argument: Yucca Mountain evolves mechanically, chemically, and hydrologically under the influence of heat. This thermal evolution has a significant impact on all aspects of repository performance, including water seepage rates, corrosion rates, dissolution chemistry, etc. See discussion for each specific FEP identified in the FEP definition for more detail.

TSPA Disposition: The temperature history of the in-drift environment is calculated explicitly as part of the *Multiscale Thermohydrologic Model*, E0120 (CRWMS M&O 2000m). Relative to EBS performance, the effect of this temperature history on chemistry is included in the rates of waste form degradation processes abstracted in F0170 (CRWMS M&O 2000p) and in the temperature-dependent equilibrium constants included in the geochemical models supporting the *Physical and Chemical Environmental Abstraction Model,* E0010 (CRWMS M&O 2000b) and its submodels. See discussion for each specific FEP identified in the FEP definition for more detail.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.04.01, Thermal (processes)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.04.02, Temperature effects (unexpected effects) (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.04.03, Heat from radioactive decay (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP. In addition it is directly related to the Primary FEP 2.1.11.01.00, heat output / temperature in waste and EBS. As discussed therein, heat from radioactive decay is the primary source of repository heating and is explicitly considered in the TSPA.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.04.04, Long-term transients (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with radioactive decay as a heat source, potential dryout from this heating, subsequent reflooding, and the effects these effects would have on the drift. As indicated in the screening discussion for the Primary, these effects are included in the TSPA.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.04.05, Time dependence (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the time dependence of the repository thermal response. As indicated in the screening discussion for the Primary, these effects are included in the TSPA.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.04.06, Coupled processes (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, TEF1, TEF2

References: E0120 (CRWMS M&O 2000m), E0010 (CRWMS M&O 2000b), F0170 (CRWMS M&O 2000p)

6.4.69 Differing Thermal Expansion of Repository Components – YMP 2.1.11.05.00

FEP Description: Thermally-induced stresses could alter the performance of the waste or EBS. For example, thermal stresses could create pathways for preferential fluid flow in the backfill or through the drip shield.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Thermal expansion induced failure (separation) of the drip shields has been screened out because the anticipated change in length is generally much less than the overlap between adjacent drip shields (see discussion in E0095 (CRWMS M&O 2000j)). Thermal expansion of other components, such as the waste package and pedestal, will not be a problem because the separation between adjacent waste packages is adequate to accommodate this small amount of expansion. WP internals (i.e., inner vs. outer barrier) have been designed to accommodate such thermal loads (CRWMS M&O 2000cc, 2000dd, 2000ee). This is further discussed in the WP and drip shield degradation FEPs AMR (CRWMS M&O 2000w).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.05.01, Differing thermal expansion of near-field barriers

Relationship to Primary FEP: This FEP is a subset of the primary FEP, and deals with the different thermal expansion of materials in contact (steel and copper in canister, canister and buffer, buffer and near-field rock, backfill and near-field rock). Because none of these design features are relevant to the Yucca Mountain repository, this FEP is not relevant.

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.11.05.02, Shearing of waste containers by secondary stresses from thermal expansion of the rock

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the potential impact of thermal expansion of the near-field rock on canister life. For the current design baseline at Yucca Mountain, the WP canisters are placed in the center of the emplacement drift, well away from the drift walls. Thus, rock thermal expansion cannot create a shear stress on the canisters. Because of this design, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.11.05.03, Differential elastic response (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (elastic response only), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.05.04, Non-elastic response (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (non-elastic response only), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST2, ENFE1, ENFE4, RDTME3

References: E0095 (CRWMS M&O 2000j)

6.4.70 Thermally-induced Stress Changes in Waste and EBS – YMP 2.1.11.07.00

FEP Description: Thermally-induced stress changes in the waste and EBS may affect performance of the repository. Relevant processes include rockfall, drift stability, changes in physical properties of the disturbed rock zone around the repository, and changes in the physical properties of the surrounding rock.

Screening Decision and Regulatory Basis: Included

Screening Argument: Repository heat at Yucca Mountain will drive the mechanical and chemical evolution of the repository and the mountain, producing durable changes. Thermal expansion (and thermo-mechanical coupling) is expected to rotate the least principal stress, currently NNW-SSE, to vertical, and after cooling, the effects of thermal contraction will rotate it back. Durable changes to the fracture flow systems are anticipated.

TSPA Disposition: Relative to the EBS analysis effort, the only relevant effect delineated above involves the impact of thermal stress on drift degradation (and thus rockfall). This is accounted for in the *Drift Degradation Analysis*, E0080 (CRWMS M&O 2000h). Impacts on the physical properties of the surrounding rock are implicitly accounted for, relative to EBS modeling, through changes in the water seepage influx boundary conditions from the NFE analysis.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.07.01, Changes in in-situ stress field (in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.07.02, Stress field changes, settling, subsidence or caving

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: CLST2, ENFE1, ENFE4, RDTME3, TEF1, TEF2

References: E0080 (CRWMS M&O 2000h)

6.4.71 Thermal Effects: Chemical and Microbiological Changes in the Waste and EBS – YMP 2.1.11.08.00

FEP Description: Temperature changes may affect chemical and microbial processes in the waste and EBS.

Screening Decision and Regulatory Basis: Included

Screening Argument: Chemical reaction and microbial process rates are very sensitive to temperature. Thus, this dependence must be accounted for.

TSPA Disposition: The effects of temperature on chemical reaction properties are included in the geochemical models supporting E0010 (CRWMS M&O 2000b) and its submodels. The effects of temperature on microbial growth are included in the *In-Drift Microbial Communities* AMR, E0040 (CRWMS M&O 2000d).

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b) and all its submodel abstractions

6.4.72 Thermal Effects on Liquid or Two-phase Fluid Flow in the Waste and EBS – YMP 2.1.11.09.00

FEP Description: Temperature differentials may result in convective flow in the waste and EBS.

Screening Decision and Regulatory Basis: Included

Screening Argument: Thermal effects may have an important influence on the rate of water contact with the waste package and/or drip shield (thereby influencing the corrosion rate) and on the rate of water influx into a failed waste package (thereby influencing the rate of waste form dissolution). Examples of this include localized dryout in the immediate vicinity of the waste packages during the early thermal phase of the repository history, as well as evaporation condensation on the underside of the drip shield providing an additional source term of water for dripping onto the waste package.

TSPA Disposition: Thermal effects on liquid or two-phase flow within the waste and EBS are explicitly accounted for in the *Multiscale Thermohydrologic Model,* E0120 (CRWMS M&O 2000m). This includes consideration of dryout near the waste packages, as well as evaporation/condensation within the drift and underneath the drip shield. The results of these analyses then feed the *EBS Radionuclide Transport Abstraction*, E0095 (CRWMS M&O 2000j).

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.09.01, Convection effects on transport (Enhanced vapor diffusion)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.09.02, Multiphase flow and gas-driven transport (water transport)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1, TEF1, TEF2

References: E00120 (CRWMS M&O 2000m), E0095 (CRWMS M&O 2000j)

6.4.73 Thermal Effects on Diffusion (Soret effect) in Waste and EBS – YMP 2.1.11.10.00

FEP Description: The Soret effect is a diffusion process caused by a thermal gradient. In liquids having both light and heavy molecules (or ions), the heavier molecules tend to concentrate in the cold region. Temperature differences in the waste and EBS may result in a component of diffusive solute flux that is proportional to the temperature gradient.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: The potential for the Soret effect should be greatest during the first 3,000 years when the maximum thermal response occurs in the repository (CRWMS M&O 2000m). However, during this time, the waste packages and drip shields will be essentially intact, and thus there will be near-zero release during this time. Later in time, the thermal gradients within the EBS are reduced. Further, the seepage flow conditions are such that the invert (the primary region through which contaminant transport occurs) is expected to remain unsaturated, further minimizing the likelihood of thermally-driven diffusion. In light of the various simplifying, conservative assumptions currently made in the *EBS Radionuclide Transport Abstraction,* E0095 (CRWMS M&O 2000j), which includes full advective and diffusive transport of all radionuclides released from the waste form with no consideration of delay mechanisms such as sorption, the neglect of the Soret effect is considered to be of negligible consequences.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.11.10.01, Soret effect (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.10.02, Thermal effects: Transport (diffusion) effects (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.11.10.03, Soret effect (water transport)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE1, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j)

6.4.74 Gas Generation – YMP 2.1.12.01.00

FEP Description: Gas may be generated in the repository by a variety of mechanisms. Gas generation might lead to pressurization of the repository, produce multiphase flow, and affect radionuclide transport. This FEP aggregates all types of gas generation into a single category. Technical discussions are presented separately for gas generation from fuel decay (FEP 2.1.12.02.00), corrosion (FEP 2.1.12.03.00), microbial degradation (FEP 2.1.12.04.00), concrete (FEP 2.1.12.02.05.00), radioactive gases within the waste (FEP 2.1.12.07.00), and radiolysis (2.1.13.01.00).

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Because the repository would be in the UZ, which is well connected to the surface, gas produced by whatever reaction is expected to escape without significant fluctuations in the total pressure within the drifts. Gas permeability, as measured in pneumatic tests, is adequate to allow escape. The calculation of the specific gas flux and composition within the EBS is delineated in the *Physical and Chemical Environmental Abstraction Model,* E0010 (CRWMS M&O 2000b).

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.12.01.01, Formation of gases (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion. Note that this FEP also discusses gas pressurization leading to expulsion of water from the repository, an effect not relevant to Yucca Mountain.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.01.02, Gas generation

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.01.03, Gas generation, buffer/backfill

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with gas generation in the buffer/backfill. Because there is no backfill/buffer in the design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.12.01.04, Chemotoxic gases (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the production of chemotoxic gases. The screening argument presented for the Primary covered all sources of gas production.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.01.05, Pressurization (in waste and EBS)

Relationship to Primary FEP: This FEP, while a subset of the Primary FEP, deals specifically with the effect of gas pressurization on salt creep. Since the Yucca Mountain repository is not situated in a salt bed, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.75 Gas Generation (He) from Fuel Decay – YMP 2.1.12.02.00

FEP Description: Helium (He) gas production may occur by alpha decay in the fuel. He production might cause local pressure buildup in cracks in the fuel and in the void between fuel and cladding, leading to cladding failure.

Screening Decision and Regulatory Basis: Excluded - Low Consequence (for EBS)

Screening Argument: He production is a result of alpha decay of actinides, so it is a consequence of the decay process. This He production could manifest itself in one of two ways. First, it could result in earlier failure of commercial spent nuclear fuel cladding as a result of higher internal gas pressures. This is a WF issue, and is discussed in the WF FEPs summary (CRWMS M&O 2000q). The second effect could be as another source of gas generation that might lead to pressurization of the repository (see FEP 2.1.12.01.00). This latter effect has already been screened out because of the placement of the repository within the UZ. Because of the inert nature of the He gas, no chemical effects (water chemistry changes) are expected.

TSPA Disposition: This FEP is excluded from the TSPA (for EBS modeling) on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.12.02.01, Helium gas production

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.02.02, Internal pressure (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness. Note that it also deals explicitly with He pressure within intact fuel pins, an effect relevant to the WF degradation analysis (and not to the EBS).

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.02.03, Gas generation, canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with gas generation and accumulation within an intact WP canister. The effect of this potential pressure on WP life is a WP issue, and is not relevant to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.02.04, Internal pressure (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with gas generation and accumulation within an intact fuel pin and an intact WP canister. The effect of this potential pressure on fuel pin and WP life is a WF and WP issue, and is not relevant to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.02.05, He gas production (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE3, RT1

References: E0010 (CRWMS M&O 2000b), CRWMS M&O 2000q

6.4.76 Gas Generation (H2) from Metal Corrosion – YMP 2.1.12.03.00

FEP Description: Gas generation can affect the mechanical behavior of the host rock and engineered barriers, chemical conditions, and brine flow, and, as a result, the transport of radionuclides. Gas generation due to oxic corrosion of waste containers, cladding, and/or structural materials will occur at early times following closure of the repository. Anoxic corrosion may follow the oxic phase, if all oxygen is depleted. The formation of a gas phase around the canister may even exclude water from the iron, thus inhibiting further corrosion.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Gas generated from corrosion of metal components within the EBS can have three influences; the hydrogen generated may impact the chemistry of the seepage flow within the drift, the hydrogen generated may blanket the metal structure and inhibit further corrosion, and the gas generated may be another contributor to potential repository pressurization. Since a repository in Yucca Mountain would be located in the UZ and therefore be well-connected to the atmosphere, it is not expected that the oxidation state of the groundwater would be affected. The primary effect may be to cause some embrittlement of the metal structures, but this is only of potential significance to the waste package and drip shield (a WP issue dealt with in the WP and drip shield degradation FEPs AMR (CRWMS M&O 2000w)). Finally, the last effect (repository pressurization) has already been screened out (see FEP 2.1.12.01.00) because of the placement of the repository within the UZ.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.12.03.01, Chemical effects of corrosion

<u>Relationship to Primary FEP:</u> This FEP is a subset of the Primary FEP and deals with the effect of corrosion products on the oxidation state of the fluid. This effect has also been previously discussed under Primary FEP 2.1.09.02.00.

<u>Screening and Disposition:</u> Same as the Primary FEP.

FEP Number and Name: 2.1.12.03.02, Effect of hydrogen on corrosion

<u>Relationship to Primary FEP:</u> This FEP is a subset of the Primary FEP and deals specifically with the potential for a hydrogen gas layer forming in the vicinity of the oxidizing metal, thereby reducing its corrosion rate. Because of the reasons presented in the screening argument for the Primary (good communication with the atmosphere), this effect is expected to be negligible. Further, ignoring this effect is conservative because it leads to higher calculated corrosion rates.

<u>Screening and Disposition:</u> Same as the Primary FEP.

FEP Number and Name: 2.1.12.03.03, Hydrogen production (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the impact of gas production on bentonite buffer. Because bentonite is not part of the current Yucca Mountain repository baseline design, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.12.03.04, Hydrogen production by metal corrosion

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.03.05, Container material inventory

Relationship to Primary FEP: This FEP is redundant with secondary FEPs 2.1.12.03.03 and 2.1.12.03.04, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.77 Gas Generation (CO_2, CH_4, H_2S) from Microbial Degradation – YMP 2.1.12.04.00

FEP Description: Microbial breakdown of cellulosic material, and possibly plastics and other synthetic materials, will produce mainly CO_2, but also other gases. The rate of microbial gas production will depend upon the nature of the microbial populations established, the prevailing conditions (temperature, pressure, geochemical conditions), and the substrates present.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: A maximum value has been set on the quantity of organic materials that could be left in the repository at the time of closure (CRWMS M&O 1995b). Further, the level of microbial activity, as discussed in E0040 (CRWMS M&O 2000d), is expected to be low. Hence, the quantity of gases generated due to microbial activity is expected to be small. As discussed for FEP 2.1.12.01.00, any such gas generated would have negligible impact on repository performance because of its being situated in the UZ.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.12.04.01, Effect of temperature on microbial gas generation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the effect of temperature on gas generation. The assessment of microbial activity discussed in E0040 (CRWMS M&O 2000d) considered the expected temperature of the repository. Thus, this FEP is implicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.04.02, Effect of pressure on microbial gas generation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the effect of pressure on gas generation. As discussed in the screening argument for the primary, elevated pressures are not expected. Thus, this FEP is implicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.04.03, Effect of radiation on microbial gas generation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the effect of radiation on microbial activity and the associated gas production. While the exact effects of radiation on microbial gas production are unknown, a conservative estimate of such gas generation is used. Thus, the effect of radiation is not expected to impact the conclusion that such gas generation has negligible consequences.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.04.04, Effect of biofilms on microbial gas generation

Relationship to Primary FEP: This FEP is a subset of the Primary FEP that deals specifically with the effect of substrates on microbial activity. The discussion pertains directly to WIPP, which has organic material as part of the waste stream, and thus is not relevant to Yucca Mountain. However, the availability of nutrients for microbial activity is explicitly addressed as part of the assessment of microbial activity discussed in E0040 (CRWMS M&O 2000d). Thus, this FEP is implicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.04.05, Methane and carbon dioxide by microbial degradation

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000d)

6.4.78 Gas Generation from Concrete – YMP 2.1.12.05.00

FEP Description: Production of gases from the aging and degradation of concrete may occur through radiolysis of water in the cement pore spaces and microbial growth on concrete.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: At Yucca Mountain, decomposition of concrete by radiolysis is not considered, because the only cementitious material (grout around rock bolts) is located far from the radiation emanating from the WP and is shielded by the surrounding rock. The character of the cementitious material degradation processes is delineated as part of the seepage/cement interactions analysis in E0010 (CRWMS M&O 2000b). The impact of these interactions on the bulk water chemistry in the EBS has been shown to be negligible (see 2.1.09.01.00), and the impact of the generated gases is ignored. As discussed for FEP 2.1.12.01.00, any such gas generated would have negligible impact on repository performance because of its being situated in the UZ.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

IRSR Issues: ENFE2, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.79 Gas Transport in Waste and EBS – YMP 2.1.12.06.00

FEP Description: Gas in the waste and engineered barrier system could affect the long-term performance of the disposal system. Radionuclides may be transported as dissolved gases or in gas bubbles. These may affect flow paths, and two-phase flow conditions may be important.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: The only normally occurring gases of concern at Yucca Mountain are $^{14}CO_2$, various radioactive fission gases, and Radon. For a repository in the UZ, these escape to the atmosphere. Thus, no significant gas buildup within the EBS occurs, and impact on flow paths is negligible.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

> **FEP Number and Name: 2.1.12.06.01, Thermo-chemical effects (related to gas in waste and EBS)**

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.06.02, Gas transport

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.06.03, Gas effects (in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.06.04, Gas escape from canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with gas flow following WP failure. It is implicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.06.05, Gas flow and transport, buffer/backfill

Relationship to Primary FEP: This FEP is a subset of the Primary FEP that deals specifically with gas flow through a bentonite buffer/backfill. Because there is no bentonite buffer/backfill in the Yucca Mountain repository baseline design, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.12.06.06, Gas transport

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.06.07, Unsaturated flow due to gas production (in waste and EBS)

Relationship to Primary FEP: This FEP deals specifically with gas generation inhibiting resaturation of the repository. Because the Yucca Mountain design baseline has the emplacement drifts located in the SZ, such resaturation would not occur even in the absence of gas generation.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.06.08, Gas permeability (in buffer/backfill)

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.12.06.05, but retained in the FEP list for completeness.

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.80 Radioactive Gases in Waste and EBS – YMP 2.1.12.07.00

FEP Description: Radioactive gases may exist or be produced in the repository. These gases may subsequently escape from the repository. Typical radioactive gases include ^{14-}C (in $^{14}CO_2$ and $^{14}CH_4$) produced during microbial degradation, tritium, fission gases (Ar, Xe, Kr), and radon.

Screening Decision and Regulatory Basis: Excluded (for EBS) - Low Consequence

Screening Argument: The radioactive gases are $^{14}CO_2$ and $^{14}CH_4$, fission gases (Ar, Xe, Kr) and radon (Rn). The CO_2, CH_4 and fission gases will in part escape from the mountain. To the extent that these have a significant contribution on the calculated source term, they are considered in the TSPA. Relative to the impact of these gases on repository performance due to pressurization effects, they are ignored. As discussed for FEP 2.1.12.01.00, any such gas generated would have negligible impact on performance of a repository situated in the UZ.

TSPA Disposition: This FEP is excluded from the TSPA (for the EBS) on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.12.07.01, Radioactive gas (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.07.02, Gaseous and volatile isotopes

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b)

6.4.81 Gas Explosions – YMP 2.1.12.08.00

FEP Description: Explosive gas mixtures could collect in the sealed repository. An explosion in the repository could have radiological consequences if the structure of the repository were damaged or near-field processes enhanced or inhibited.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: As discussed under FEPs YMP 2.1.12.01.00 through 2.1.12.05.00, there are a number of sources for gas generation, some of which result in the production of flammable gases (H_2, CH_4, and C_2H_2). Generally however, the permeability of Yucca Mountain to air will provide an adequate condition for the flammable/explosive gases to be diluted, diffused, and/or dispersed before they could reach explosive concentrations. Possibly gases, as well as water, could accumulate, if there was a condensation cap or reduced permeability. However, no viable ignition source can be identified. Further, the possibility of a condensation cap has been essentially eliminated in the current design by greatly increasing the distance between the disposal tunnels (CRWMS M&O 2000bb). The possibility of reduced permeability to gas would also limit the availability of oxygen for combustion and greatly reduce the corrosion of containers, thereby reducing the number of containers potentially producing flammable/explosive gases.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.12.08.01, H2/O2 explosions (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.08.02, Flammability (in waste and EBS)

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.08.03, Explosions

Relationship to Primary FEP: A portion of this FEP is redundant with the Primary FEP. However, this FEP also deals with bomb blasts at the surface of the repository. Such acts of war or sabotage are outside the scope of the TSPA.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.12.08.04, Explosion

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.12.08.03, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE3, ENFE4, RT1

References: CRWMS M&O 2000bb

6.4.82 Radiolysis – YMP 2.1.13.01.00

FEP Description: Alpha, beta, gamma, and neutron irradiation of water can cause dissociation of molecules, leading to gas production and changes in chemical conditions (Eh, pH, concentration of reactive radicals).

Screening Decision and Regulatory Basis: Excluded – Low Consequence (for EBS)

Screening Argument: Alpha, beta, gamma, and neutron irradiation of water leads to the potential formation of highly reactive excited and ionized species, which in turn can undergo various chemical reactions. In pure water, the final products are hydrogen and oxidants. In addition, the oxidants formed may, for example, react with dissolved iron (+2), which will decrease the net yield of oxidants. Thus, potential radiolysis may produce more aggressive fluids, both for waste form degradation and waste package and drip shield corrosion, as well as an additional source of gas.

The potential impact of radiolysis on waste form degradation is not an EBS issue, but rather is discussed in the miscellaneous waste form FEPs AMR (CRWMS M&O 2000q).

During the time period where radiolysis may impact waste package and drip shield corrosion and failure, the waste materials that are the source of the radiation field will still be contained within the waste packages. Thus, outside the WP only radiolysis due to gamma and neutron radiation would be expected, because of the shielding from both cladding and the waste package itself. At this time, the amount of water in the drift is relatively small. The water is in the form of humidity in the air with at best a wet layer on the metal surfaces. Thus, there is relatively little material to stop the penetrating neutron and gamma fluxes, and it is expected that the majority of this flux will be absorbed by the surrounding host rock. Thus, little radiolysis is expected within the drift. Radiolysis may also occur within the WP both prior to and after failure. To the extent that radiolysis may lead to the accelerated corrosion through the production of hydrogen peroxide, this was addressed in the WP FEPs AMR (CRWMS M&O 2000w) and excluded on the basis of low consequence.

In addition to potentially impacting waste package and drip shield failure timing, radiolysis could also be an additional source of gas within the repository, both relative to changing the gas composition within the EBS and increasing gas pressure. These effects would also be expected to be negligible based on the previous arguments. In addition, any effects that could occur have already been screened out as a result of low consequence to expected dose as discussed under FEPs 2.1.12.01.00 (gas generation) and 2.1.09.06.00 (redox potential in waste and EBS).

TSPA Disposition: This FEP is excluded from the TSPA for EBS modeling on the basis of low consequence to dose.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.13.01.01, Radiolysis (in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.02, Radiolysis

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.03, Radiolysis (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the issue of hydrogen generation close to the waste form. Thus, it is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.04, Radiolysis (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (dealing with radiolysis prior to canister failure), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.05, Radiolysis prior to wetting (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the potential for radiolysis within the WP prior to failure, and the impact this could have on WP failure time. This is a WF and WP issue and not relevant to EBS performance.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.06, Radiolysis of brine

Relationship to Primary FEP: Although the specific words that describe this FEP pertain to WIPP brine, it nevertheless deals with the issue of radiolysis in the fluid near the waste. As such, this FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.07, Radiolysis of cellulose (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the radiolysis of organic waste materials (WIPP). Since organic waste materials are not part of the Yucca Mountain design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.13.01.08, Radiolysis

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.01.09, Radiolysis

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

IRSR Issues: ENFE2, ENFE3, ENFE4, RT1

References: CRWMS M&O 2000q, CRWMS M&O 2000w

6.4.83 Radiation Damage in Waste and EBS – YMP 2.1.13.02.00

FEP Description: Strong radiation fields could lead to radiation damage to the waste forms and containers (CSNF, DSNF, DHLW), backfill, drip shield, seals, and surrounding rock.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Radiation damage that affects mobilization of contaminants is included in the data describing such mobilization and is therefore implicitly included in modeling. Further, this is a WF issue as discussed in the WF FEPs summary (CRWMS M&O 2000q). Radiation damage to the waste packages and/or drip shields is a WP issue as discussed in the WP FEPs summary (CRWMS M&O 2000w). Radiation damage to other EBS structural components is expected to be negligible (CRWMS M&O 2000kk). Further, even if there were any damage to the pedestal, its failure is already assumed in the *EBS Radionuclide Transport Abstraction*, E0095 (CRWMS M&O 2000j). Thus, the consequences associated with this FEP relative to pedestal failure are already bounded in the current TSPA analysis.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.1.13.02.01, Radiation effects (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the effects of radiation on the rock and associated groundwater chemistry. It is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.02, Radiation effects on bentonite

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the effects of radiation on bentonite. Because there is no bentonite buffer/backfill in the yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.13.02.03, Material property changes (due to radiation in waste and EBS)

Relationship to Primary FEP: No description beyond the FEP title is provided in the database. Based on interpretation of the FEP title, this FEP is a subset of the Primary FEP, and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.04, Radiation damage (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing with glass swelling from radiation. This is a WF issue and not relevant to EBS performance.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.05, Radiation shielding (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (inhibition of radiolysis due to canister shielding), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.06, Radiation effects on buffer/backfill

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the effects of radiation on buffer/backfill. Because there is no buffer/backfill in the yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

FEP Number and Name: 2.1.13.02.07, Radiation effects on canister

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the effect of radiation on the WP properties. This is a WP issue and not relevant to EBS performance.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.08, Radiological effects on waste

Relationship to Primary FEP: This FEP is a subset of the Primary FEP dealing specifically with the effect of radiation on the WF. This is a WF issue and not relevant to the EBS.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.09, Radiological effects on containers

Relationship to Primary FEP: This FEP is redundant with secondary FEP 2.1.13.02.07, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.10, Radiological effects on seals

Relationship to Primary FEP: This FEP is a subset of the Primary FEP (seal degradation), and is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.1.13.02.11, Radiological effects on canisters

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals specifically with the effect of radiation on copper canisters. Because copper canisters are not used as part of the Yucca Mountain repository design baseline, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: All

References: E0095 (CRWMS M&O 2000j), CRWMS M&O 2000q, CRWMS M&O 2000w

6.4.84 Mutation – YMP 2.1.13.03.00

FEP Description: Radiation fields could cause mutation of micro-organisms, leading to unexpected chemical reactions and impacts.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Microbes can affect the mobility of colloidal material as well as influence the rate of waste package corrosion. Given present knowledge, estimates of the effects of microbes on corrosion processes are highly uncertain; the potential effects of mutated microbes are more uncertain. No analyses or experimental research have been performed to investigate this problem specifically. However, general principles of population genetics indicate that most mutations are either neutral or deleterious to the fitness of an organism and, in the absence of strong natural selection, are unlikely to produce any definite change in the phenotypes of the organisms. Thus, exclusion of effects of mutated microbes from TSPA is considered to be conservative.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

IRSR Issues: CLST1, ENFE2, ENFE3, ENFE4, RT1

References: E0010 (CRWMS M&O 2000b), E0040 (CRWMS M&O 2000d)

6.4.85 Elemental Solubility in Excavation Disturbed Zone – YMP 2.2.01.04.00

FEP Description: Radionuclide solubility limits in the excavation-disturbed zone may differ from those in the waste and EBS.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: Diffusion of radionuclides through the invert into the surrounding rock is a function not only of the diffusion coefficient in the invert, but also of the solubility limit in the surrounding rock if this impacts concentration at the EBS boundary. Thus for example, a reduced solubility limit in the near field could act to increase the diffusion rate through the invert and thus out of the EBS. For purposes of the TSPA, however, this is not a significant issue from a dose (increase) perspective. The modeling of diffusion through the invert conservatively assumes that the radionuclide concentration is zero at the EBS boundary. This maximizes the rate of diffusion through the invert. Accounting for the actual concentration of radionuclides at the EBS boundary could only serve to lower the rate of radionuclide release from the EBS. Thus, the exclusion of this FEP (as it is described in the database) is based on low consequences (increase) to the expected dose.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence, by using a bounding (conservative) assumption to calculate radionuclide diffusion in the EBS.

IRSR Issues: ENFE4, RT1

References: E0095 (CRWMS M&O 2000j)

6.4.86 Episodic/Pulse Release from Repository – YMP 2.2.07.06.00

FEP Description: Episodic release of radionuclides from the repository and radionuclide transport in the UZ may occur both because of episodic flow into the repository, and because of other factors including intermittent failures of waste packages.

Note that this FEP also encompasses FEP ebs # 16 from Table 4.

Screening Decision and Regulatory Basis: Included (episodic flow into the EBS), Excluded – Low Consequence (pulse release of radionuclides)

Screening Argument: Pulse releases have been screened out because a "bathtub model", which would generate a pulse release from a failed WP, has been shown to be nonconservative relative to the flow-through model used in the *EBS Radionuclide Transport Abstraction*, E0095 (CRWMS M&O 2000q).

TSPA Disposition: Episodic flow is explicitly included through an idealized treatment of climate change (discrete periods of constant climate) and the associated impact on seepage inflow to the drifts (boundary condition from the NFE analysis). Pulse releases are screened out on the basis of low consequence.

IRSR Issues: ENFE1, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j)

6.4.87 Redissolution of Precipitates Directs More Corrosive Fluids to Containers – YMP 2.2.08.04.00

FEP Description: Redissolution of precipitates that have plugged pores as a result of evaporation of groundwater in the hot zone, produces a pulse of fluid reaching the waste containers when gravity-driven flow resumes, which is more corrosive than the original fluid in the rock.

Screening Decision and Regulatory Basis: Included

Screening Argument: The water chemistry of the seepage into the drift is included as a model within the TSPA.

TSPA Disposition: The process of redissolution of mineral precipitates is explicitly included in the drift-scale thermal-hydrologic/chemical model as part of the NFE analysis. Thus, this effect is implicitly included as part of the boundary condition to the EBS analysis. This FEP is discussed in more detail in the NFE FEPs AMR (CRWMS M&O 2000r).

IRSR Issues: ENFE1, ENFE3, ENFE4, RT1

References: E0095 (CRWMS M&O 2000j), E0010 (CRWMS M&O 2000b), E0105 (CRWMS M&O 2000l)

6.4.88 Gas Pressure Effects – YMP 2.2.11.02.00

FEP Description: Pressure variations due to gas generation may affect flow patterns and contaminant transport in the geosphere.

Screening Decision and Regulatory Basis: Excluded - Low Consequence

Screening Argument: For a repository located in the UZ at Yucca Mountain, the connections to the atmosphere assure that a significant buildup of gas pressure is not likely. Studies on 2-phase flow are, however, just beginning to consider certain special aspects of the problem.

TSPA Disposition: This FEP is excluded from the TSPA on the basis of low consequence.

Treatment of Secondary FEPs: The following secondary FEPs are addressed by this primary FEP:

FEP Number and Name: 2.2.11.02.01, Gas pressure effects

Relationship to Primary FEP: This FEP is redundant, but retained in the FEP list for completeness.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.2.11.02.02, Fluid flow due to gas pressurization (in waste and EBS)

Relationship to Primary FEP: This FEP is a subset of the Primary FEP and deals with the effect of gas pressurization on groundwater flow. Because of the location of the repository in the UZ, this FEP is explicitly considered in the screening argument discussion.

Screening and Disposition: Same as the Primary FEP.

FEP Number and Name: 2.2.11.02.03, Disruption due to gas effects

Relationship to Primary FEP: This FEP is a subset of the Primary FEP, but deals with the specific repository configuration associated with the WIPP site. Because the proposed repository is located at Yucca Mountain, there is less than one chance in 10,000 in 10,000 years that this FEP will occur (it is not relevant to the Yucca Mountain repository design).

Screening and Disposition: Excluded on the basis of low probability (not credible).

IRSR Issues: ENFE1,RT1

References: E0010 (CRWMS M&O 2000b)

7. CONCLUSIONS

This AMR documents the screening of Primary database FEPs (Section 6.4) that are relevant to the EBS (Table 1), resulting in decisions for inclusion in or exclusion from TSPA scenarios. Table 8 provides a summary of these decisions, along with the basis for any "Exclude" determinations. EBS process model considerations that were used as background in the process screening are summarized in Attachment I. This screening process was done for the EDA-II repository design, which did not include the use of backfill (as had been considered for an earlier revision of this document). To the extent that the inclusion of backfill (as a result of a future design change) would impact these screening decisions, this was noted in Table 8. In addition, a process for identifying EBS FEPs independently from the database was developed (Section 6.2) to ensure completeness. This resulted in the identification of a set of redundant EBS FEPs (Table 4) that are correlated with the FEPs database (Table 6). Finally, for each of the EBS Primary FEPs, the associated Secondary FEPs were considered to ensure that they were encompassed by the Primary FEP description and screening decision (Section 6.4). A complete summary of the include/exclude determinations, along with the basis for any "Exclude" determination, for both the Primary and Secondary FEPs is provided in Table 9.

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the technical product input information quality may be confirmed by review of the DIRS Database.

8. INPUTS AND REFERENCES

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8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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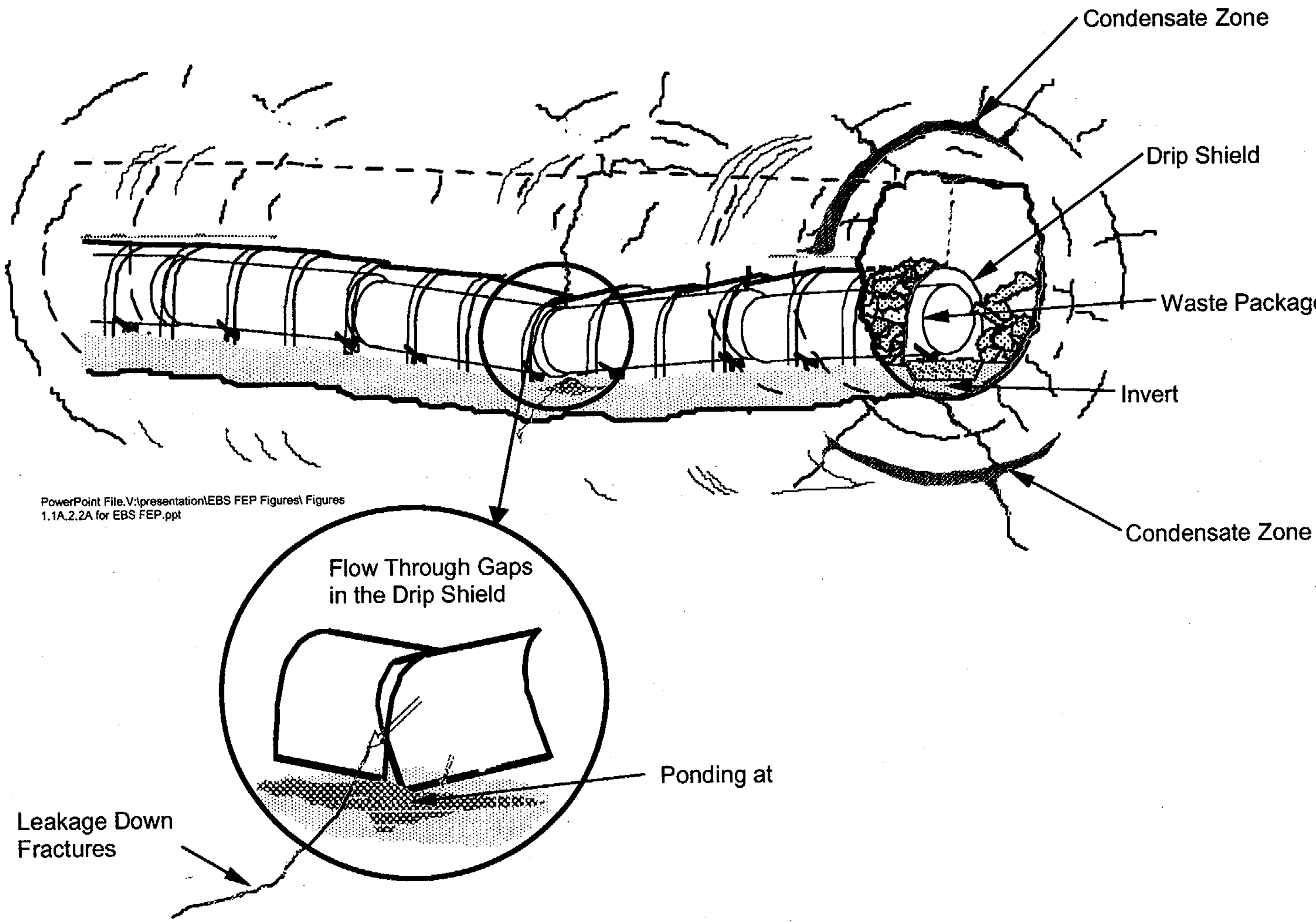


Figure 1. Floor Heave with Downward Displacement

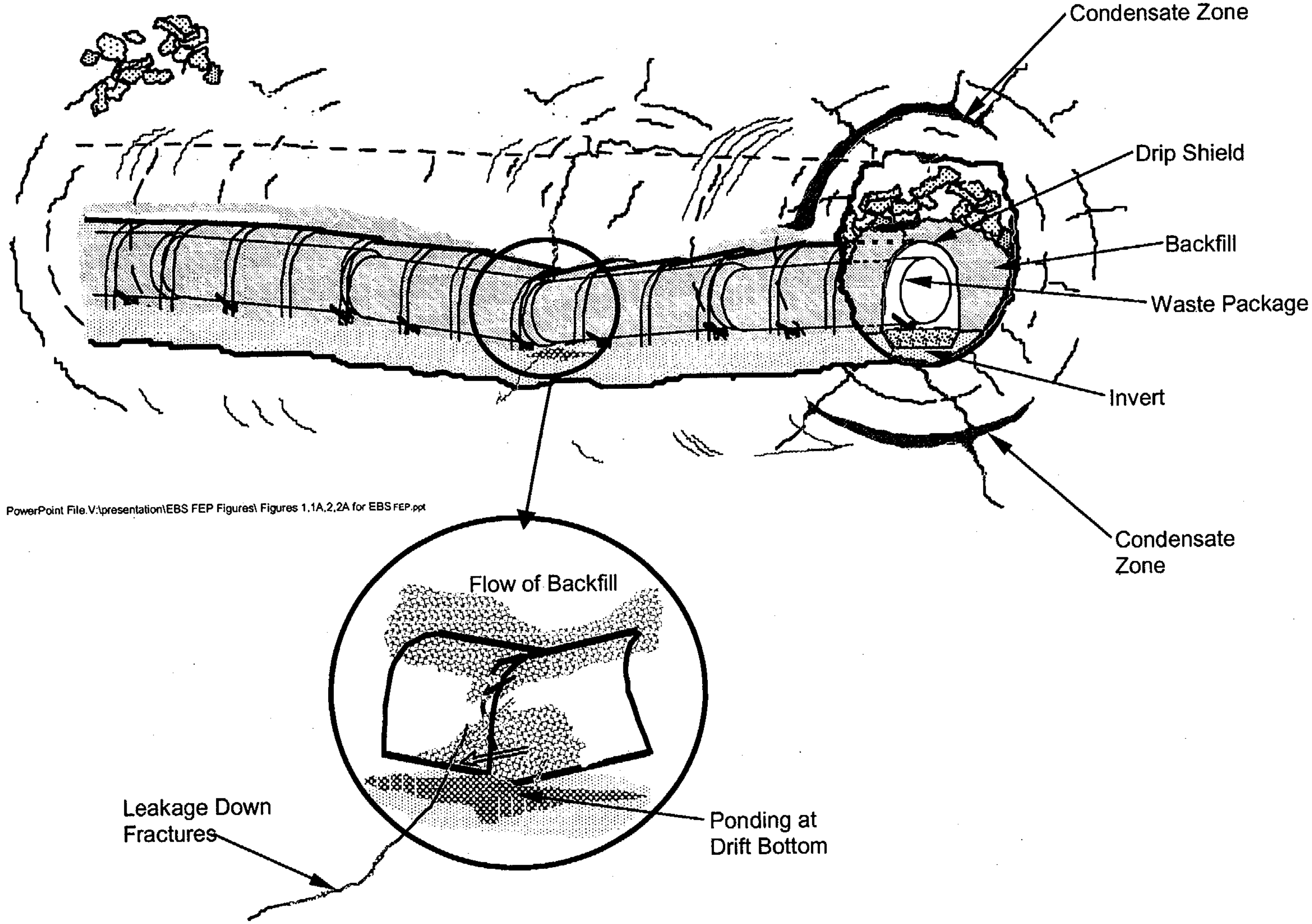


Figure 1A. (Backfill Option) Floor Heave with Downward Displacement

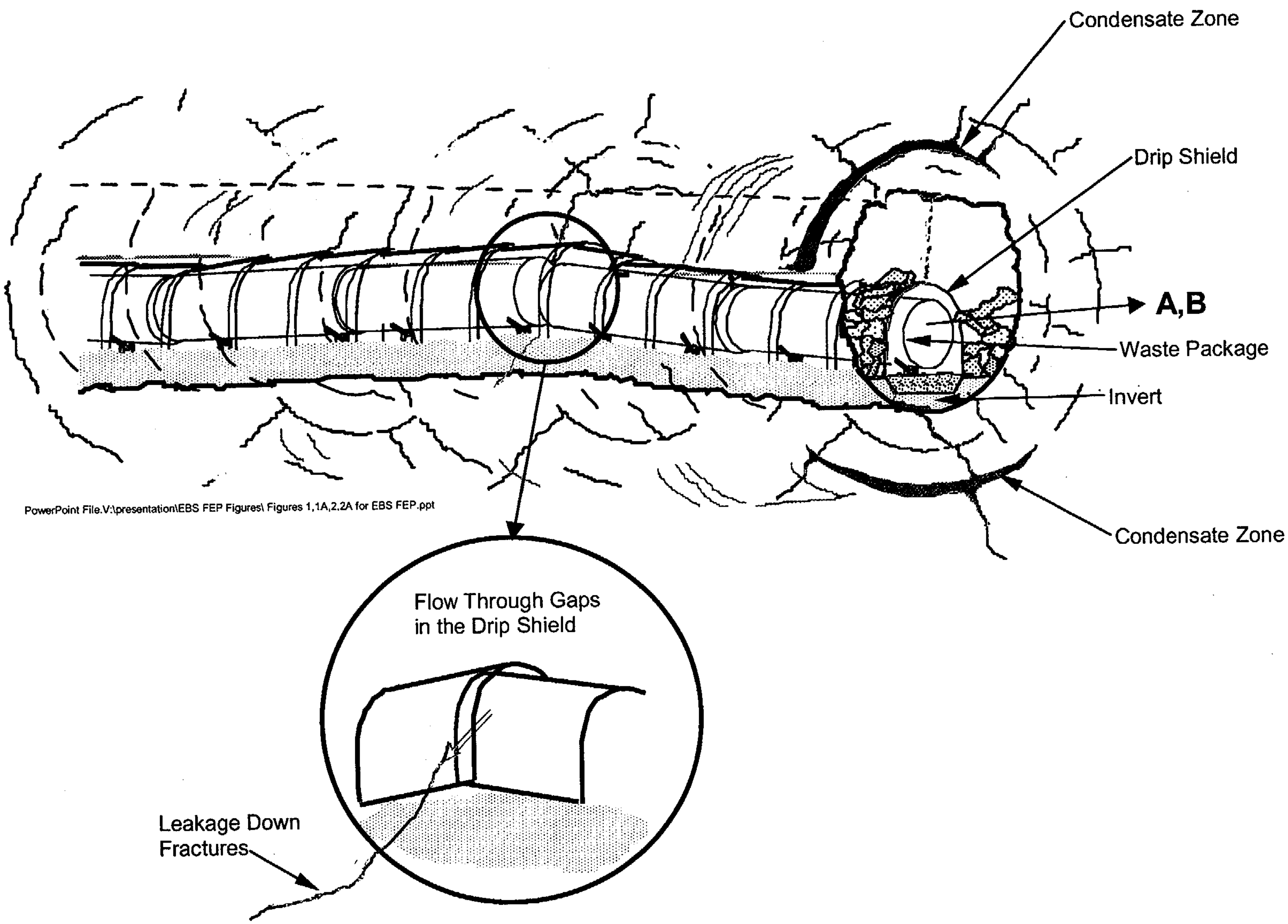


Figure 2. Floor Heave with Upward Displacement

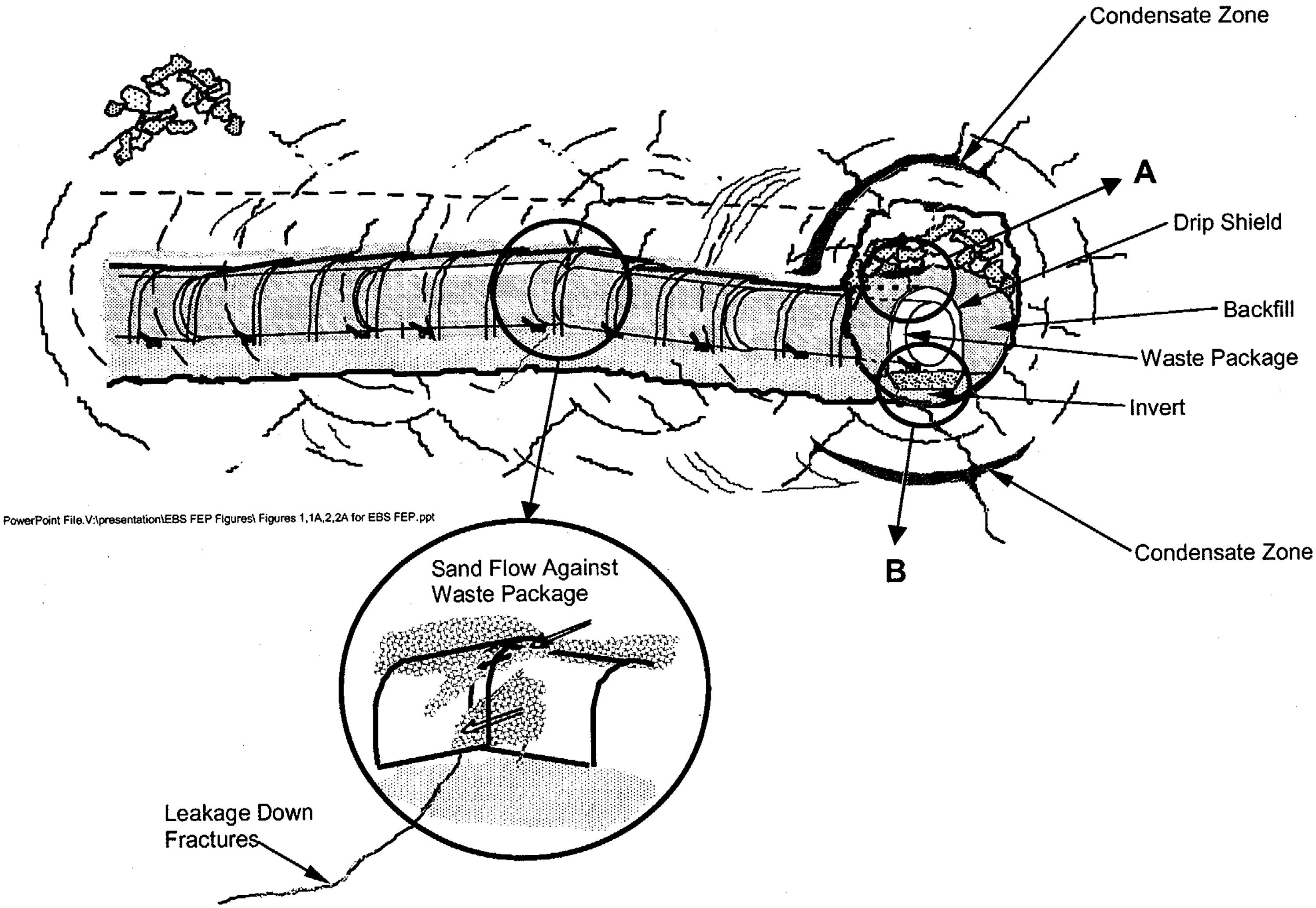
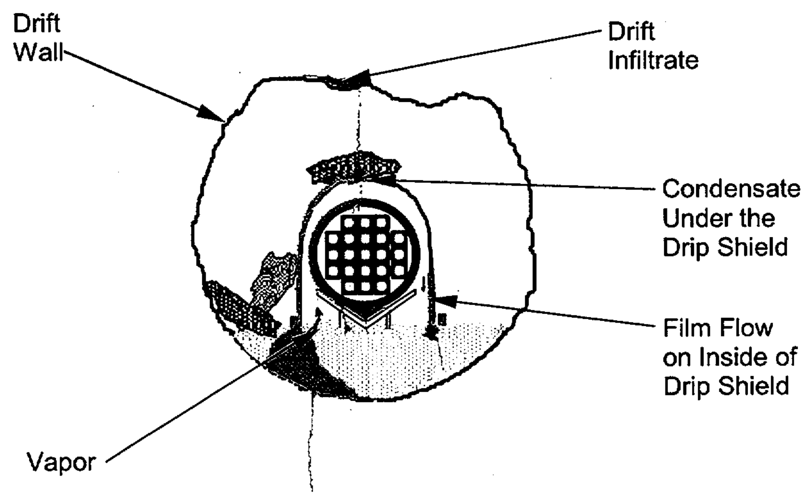
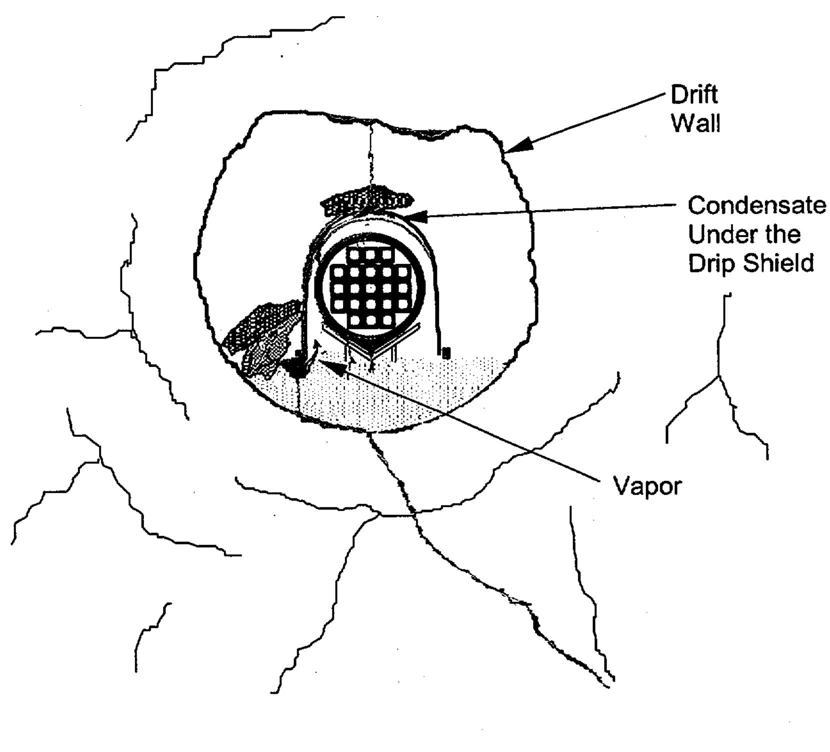


Figure 2A. (Backfill Option) Floor Heave with Upward Displacement

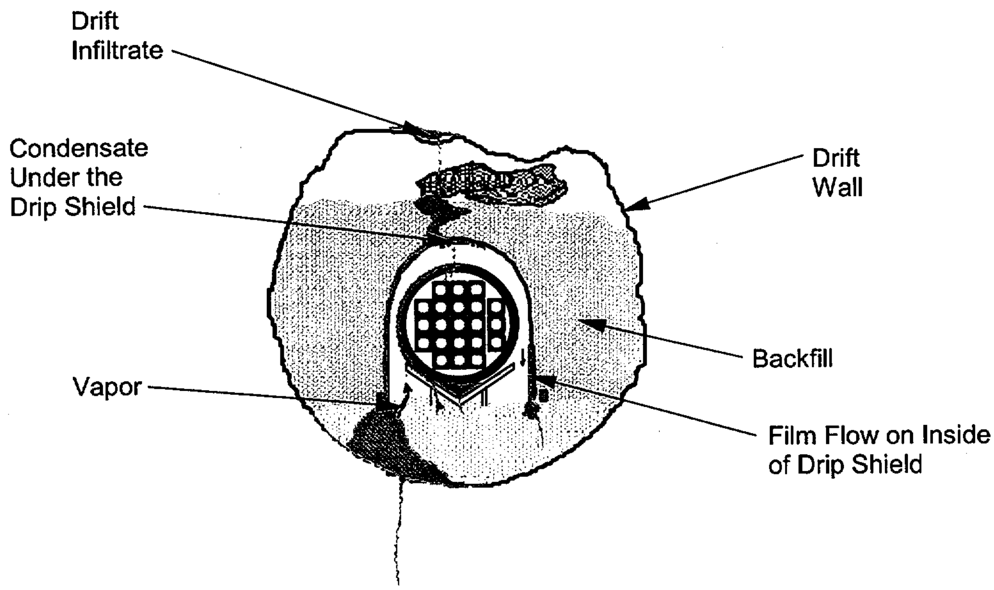


A. FLOW AROUND DRIP SHIELD

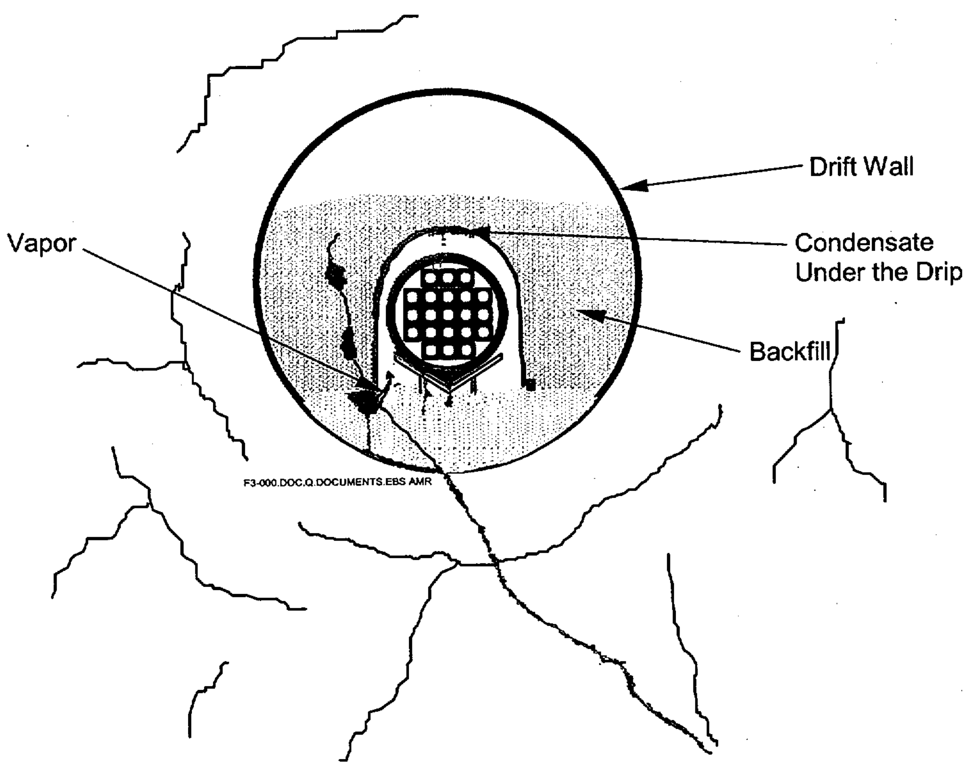


B. FLOW THROUGH AND BETWEEN DRIP SHIELDS

Figure 3. Cross-Sections of the Drift Depicting the Degradation in Regions A and B of Figure 2



A. FLOW AROUND DRIP SHIELD



B. FLOW AROUND DRIP SHIELD

Figure 3A. (Backfill Option) Cross-Sections of the Drift Depicting the Degradation in Regions A and B of Figure 2

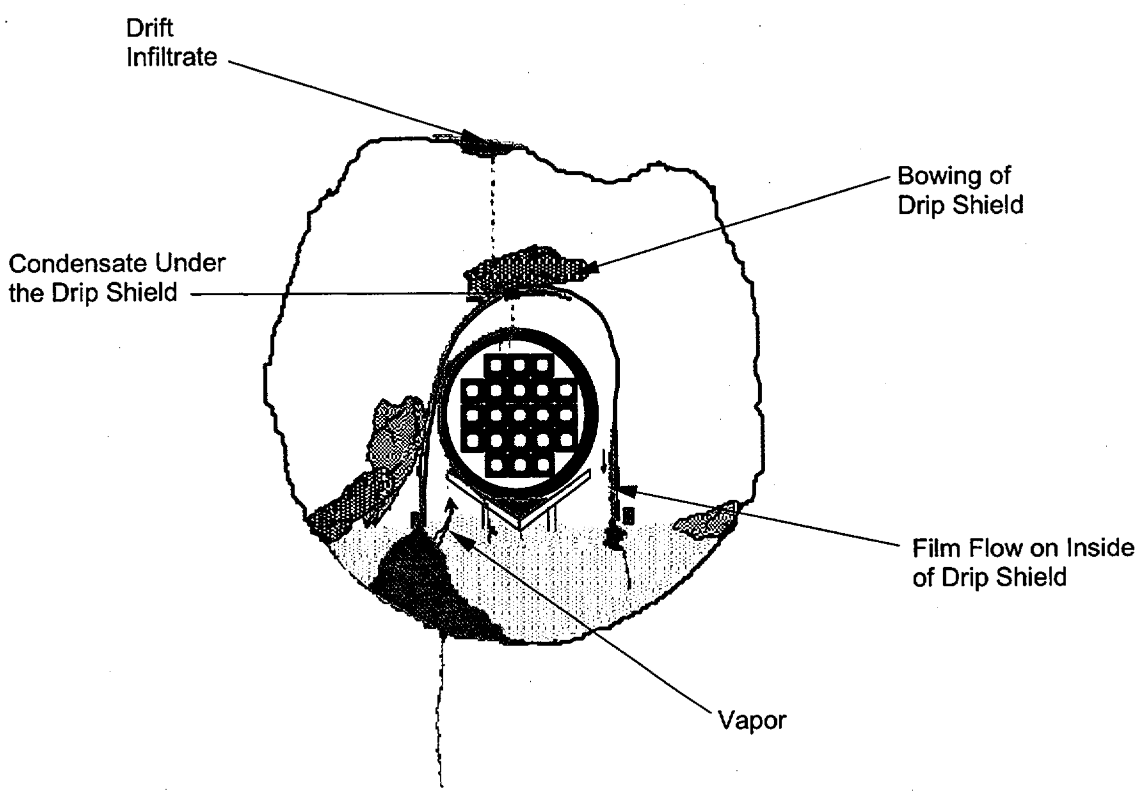


Figure 4. Cross-Section of the Drift with an Intact Drip Shield Distorted by Rockfall Sufficient to Contact a Waste Package

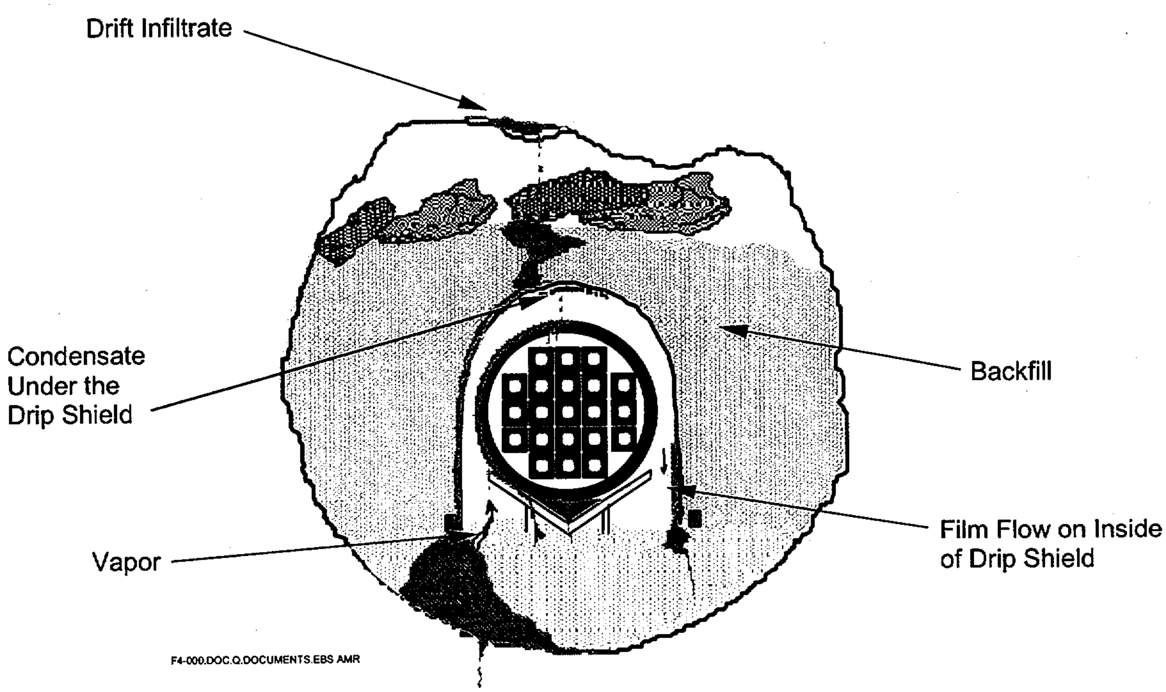


Figure 4A. (Backfill Option) Cross-Section of the Drift with an Intact Drip Shield Not Distorted Due to Effects of Backfill Protection

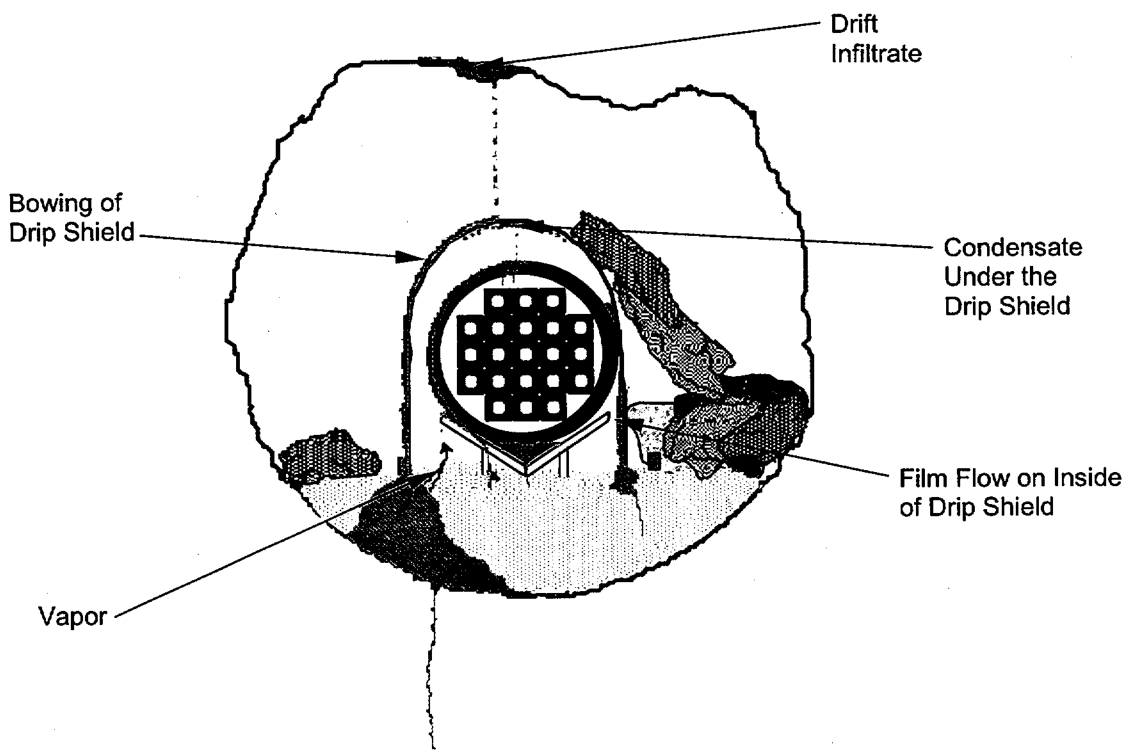


Figure 5. Cross-Section of the Drift with an Intact Drip Shield Displaced Laterally by Rockfall Sufficient to Contact a Waste Package

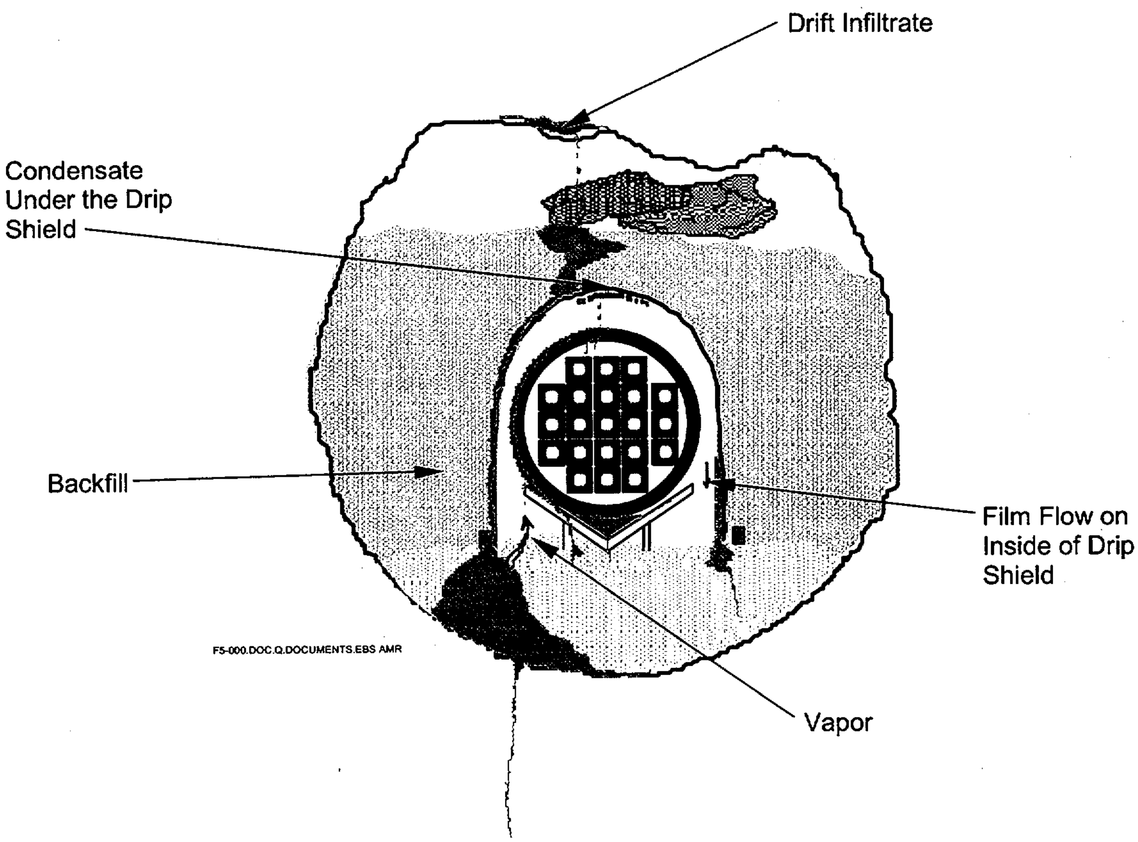


Figure 5A. (Backfill Options) Cross-Section of the Drift with an Intact Drip Shield Not Displaced Laterally Due to Backfill Protection

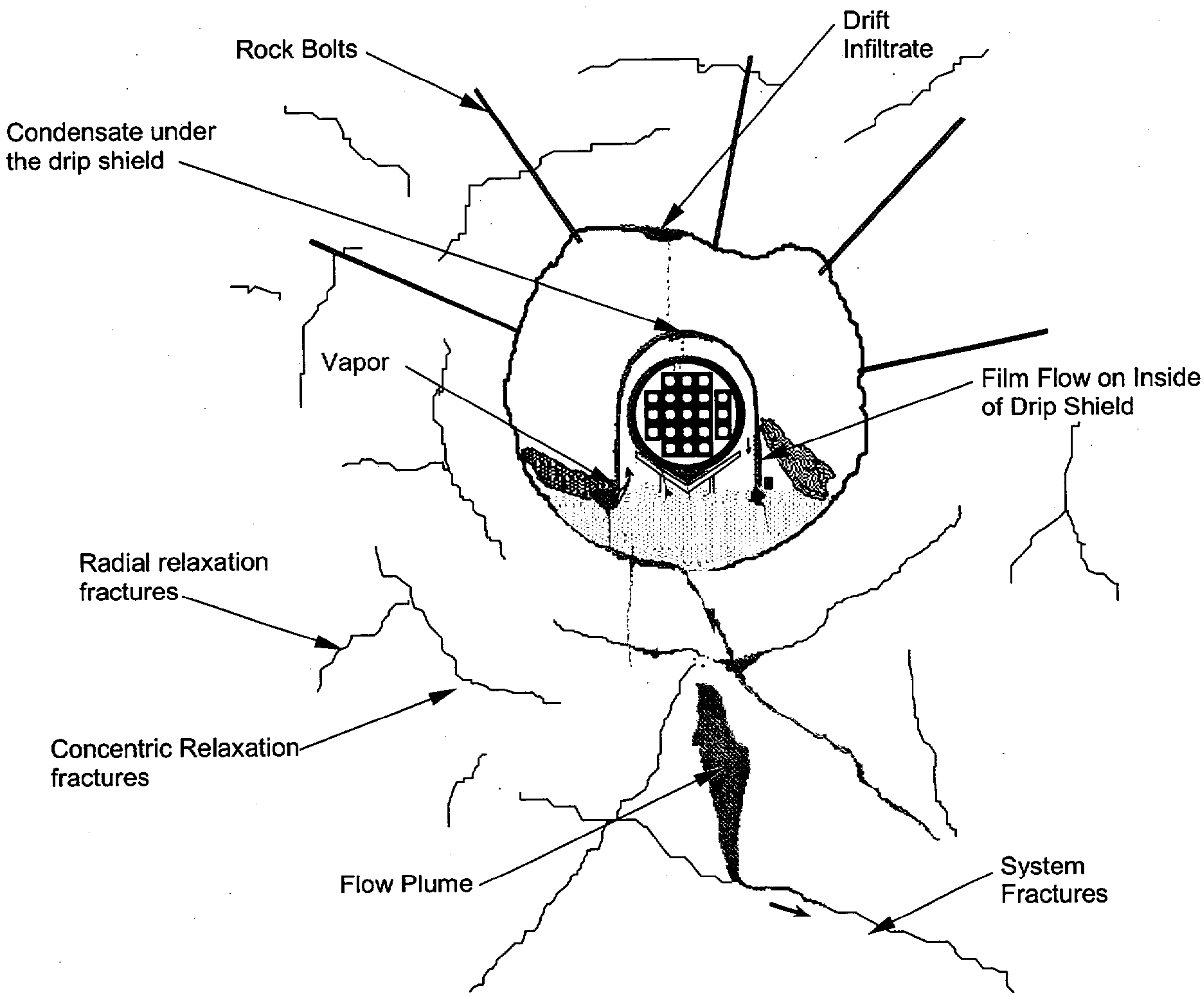


Figure 6. Cross-Section of the Drift Illustrating Rock Matrix and Fracture Flow Paths

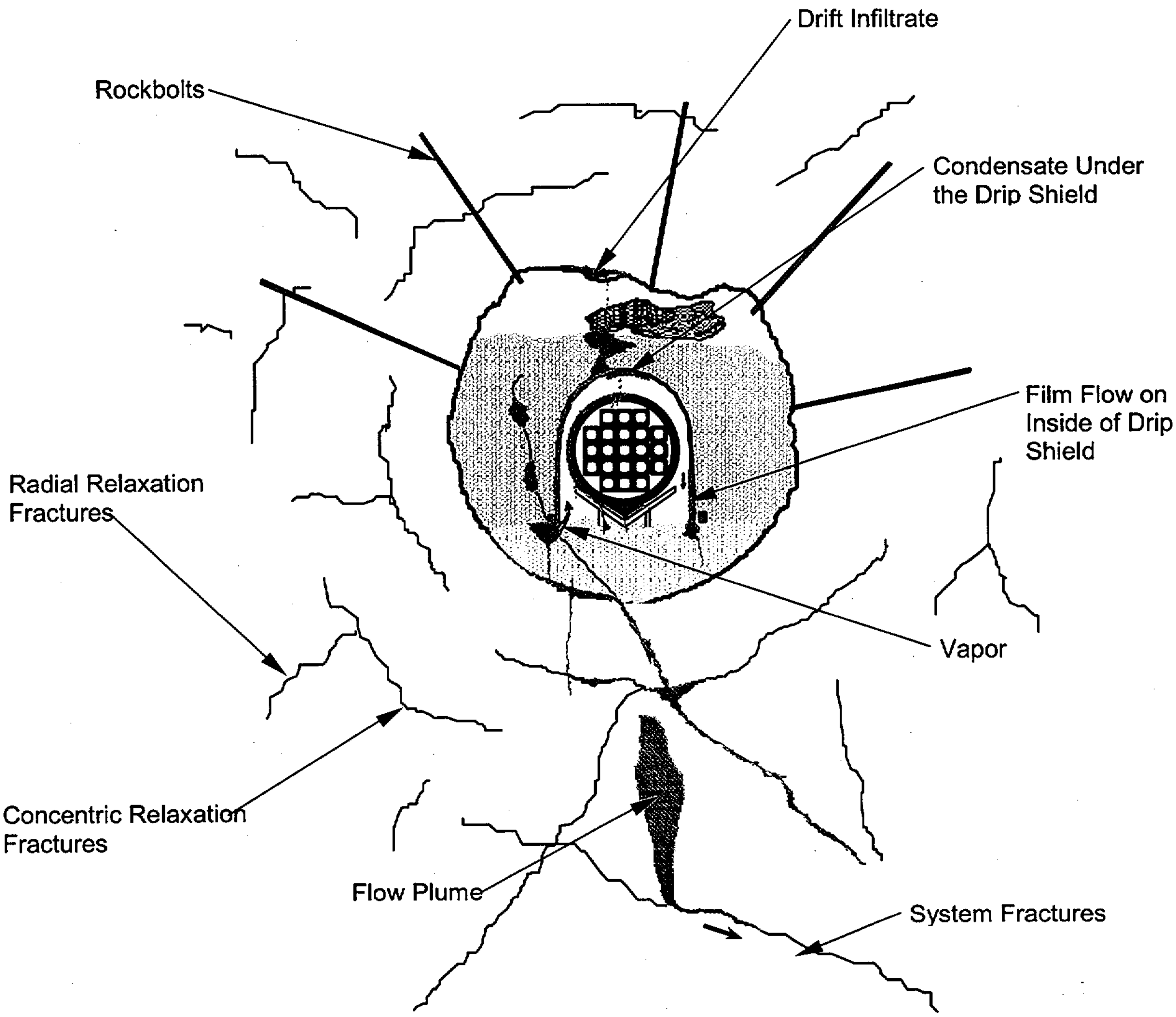
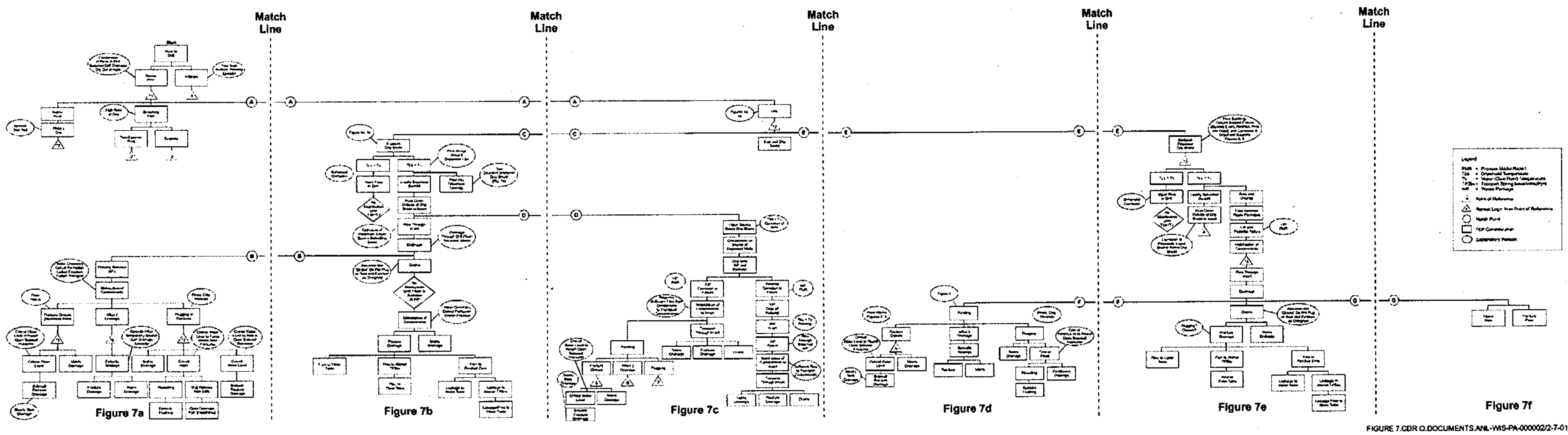
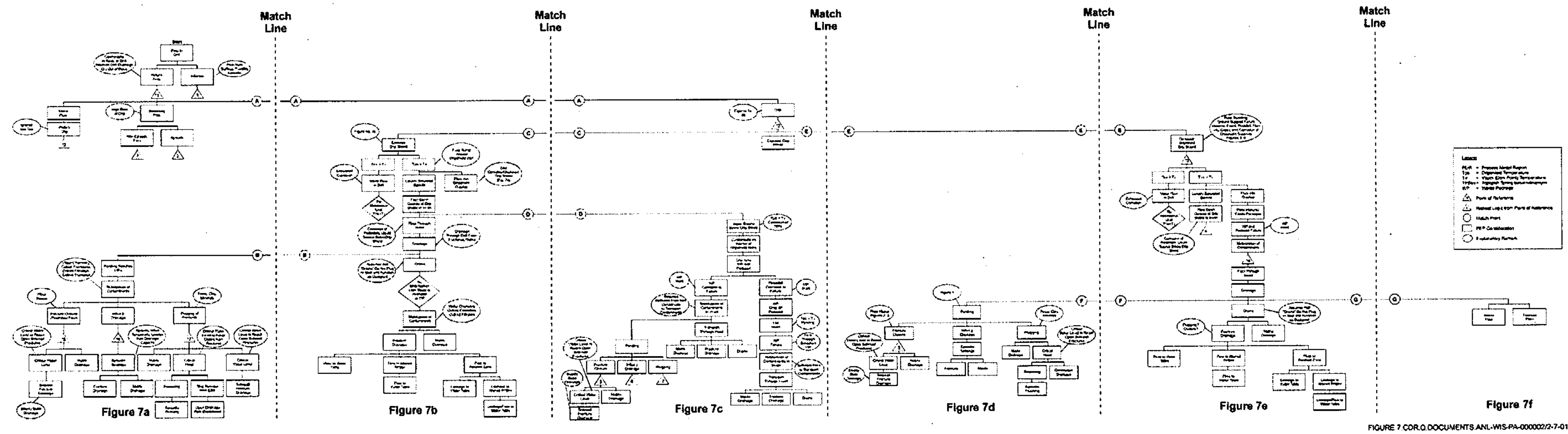


Figure 6A. (Backfill Option) Cross-Section of the Drift Illustrating Rock Matrix and Fracture Flow Paths



Logic Tree Detail Presented in Figures 7a through 7f

Figure 7. EBS FEP Logic Tree (FEPs Are Identified for the Expected Behavior)



Logic Tree Detail Presented in Figures 7A-a through 7A-f

Figure 7A. (Backfill Option) EBS FEP Logic Tree (FEPs are Identified for the Expected Behavior)

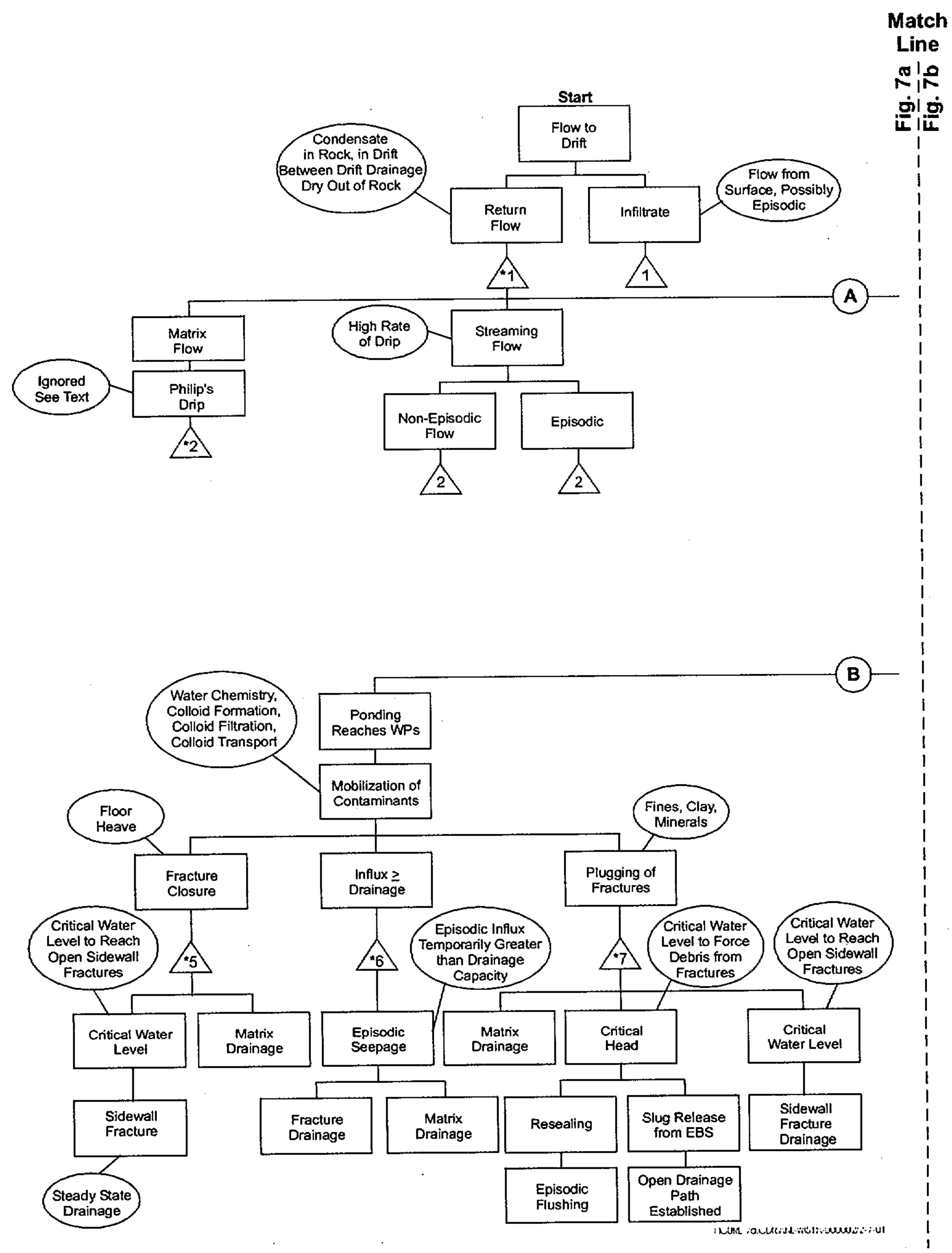


Figure 7a. Part 7a of Figure 7
(See Legend in Figure 7f)

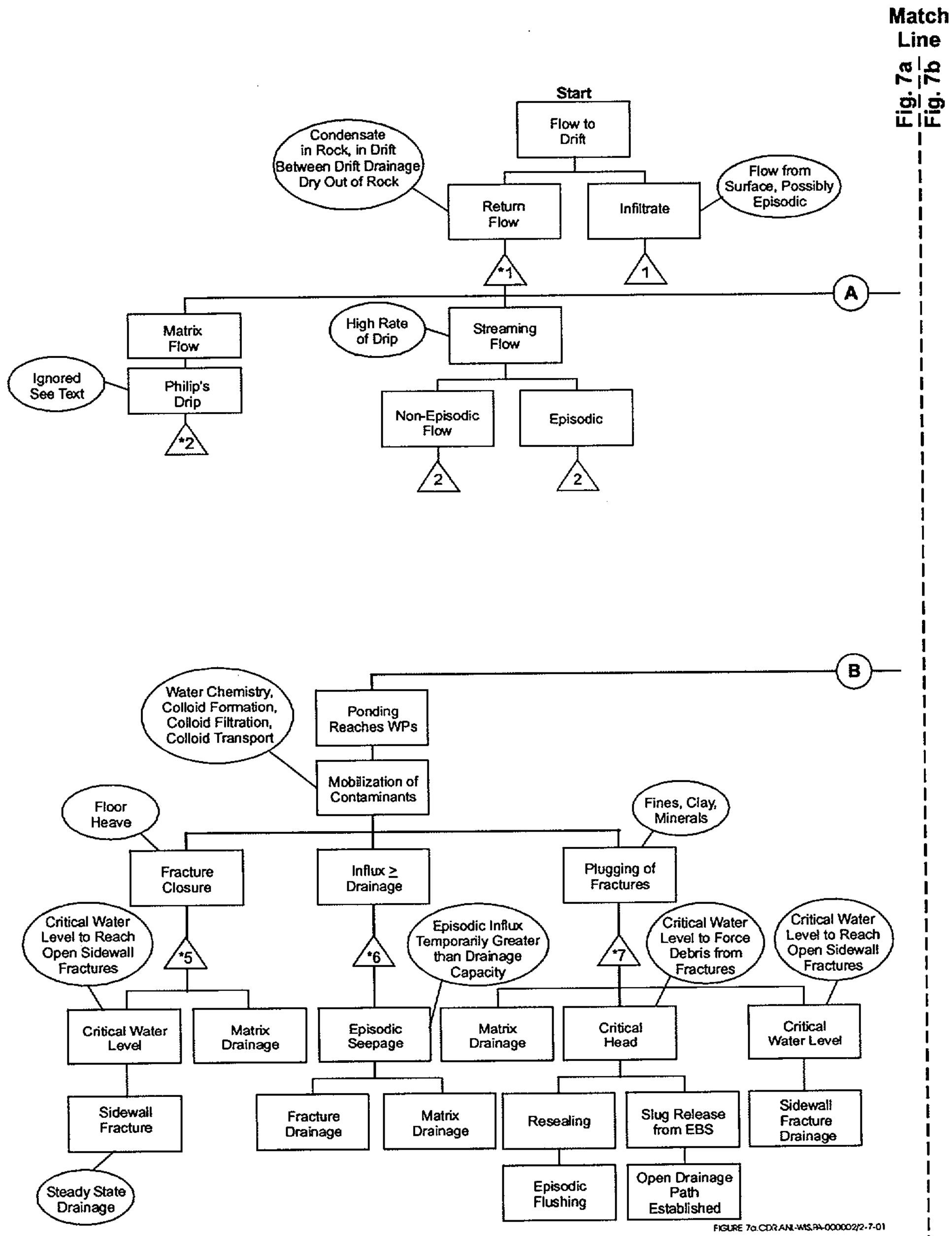


Figure 7a. Part 7a of Figure 7
(See Legend in Figure 7f)

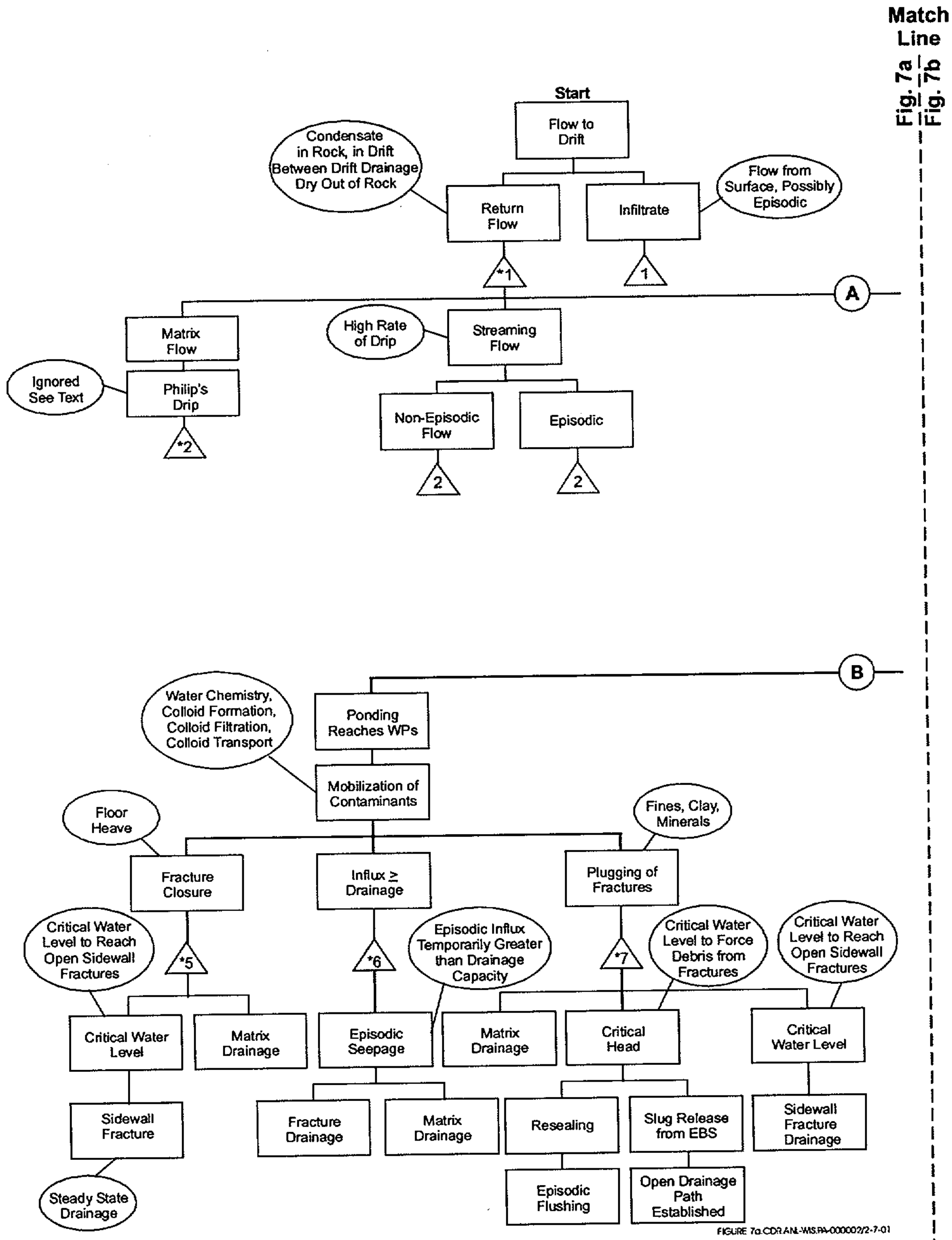


Figure 7A-a. (Backfill Option) Part 7A-a of Figure 7A
(See Legend in Figure 7A-f)

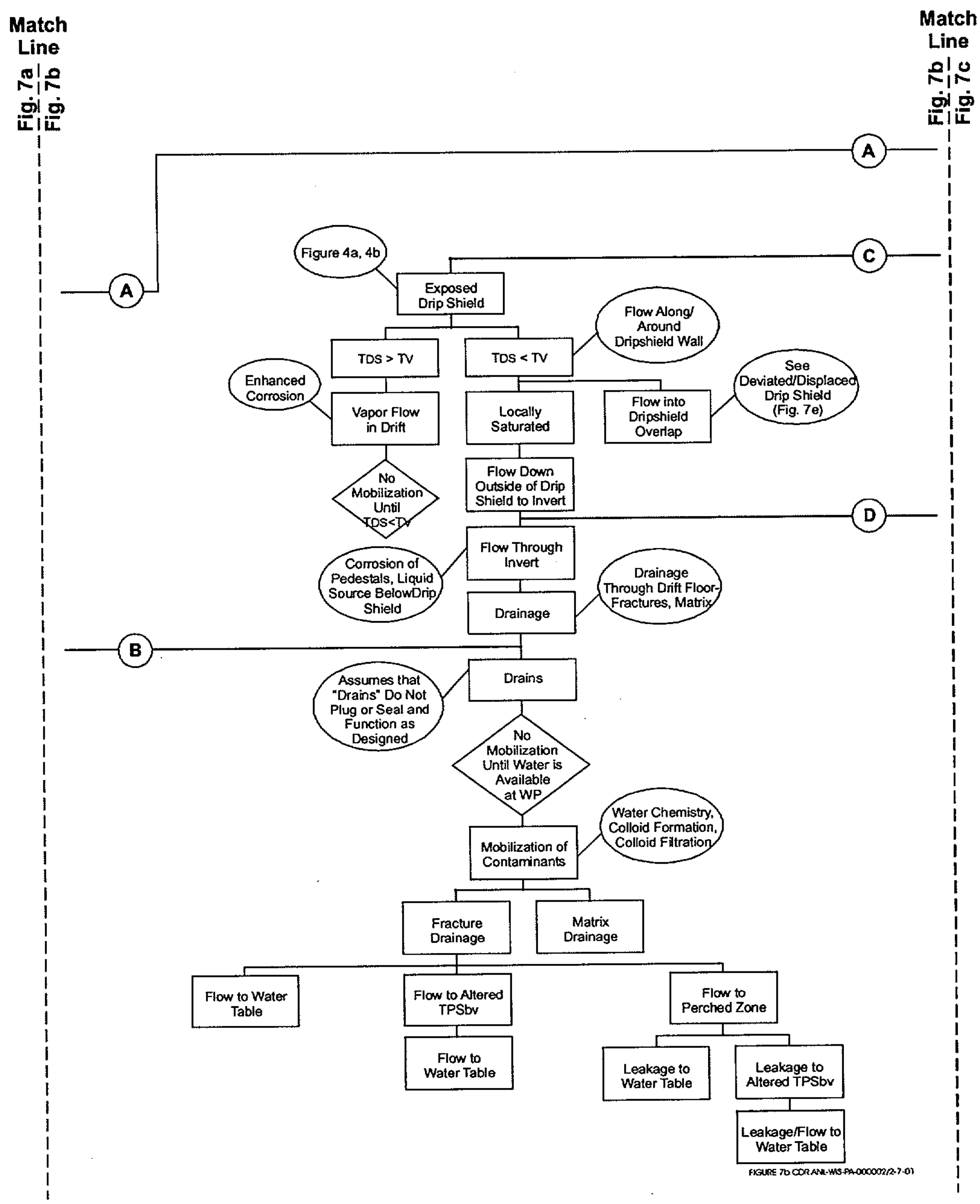
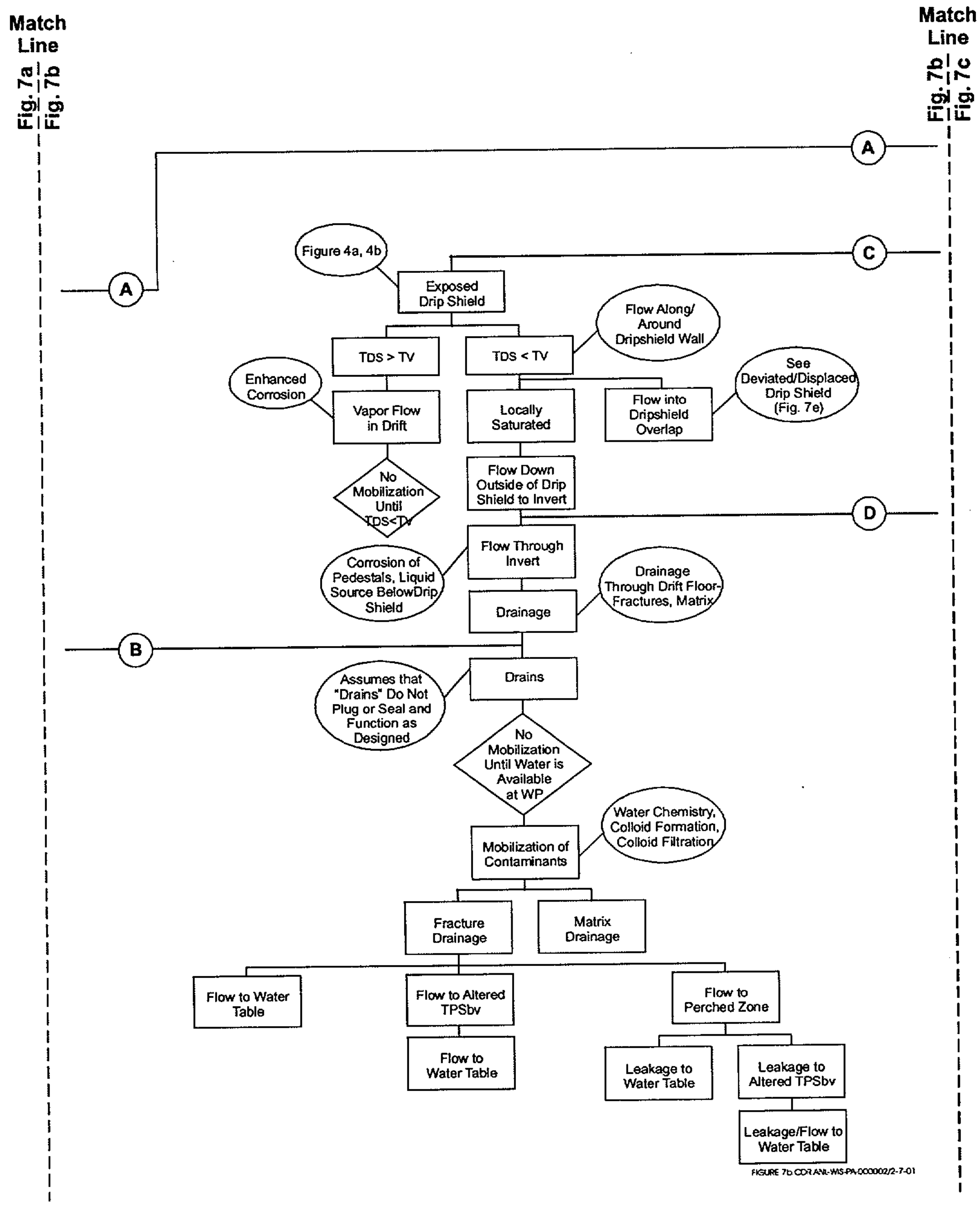


Figure 7b. Part 7b of Figure 7
(See Figure Legend in Figure 7f)



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(See Figure Legend in Figure 7A-f)

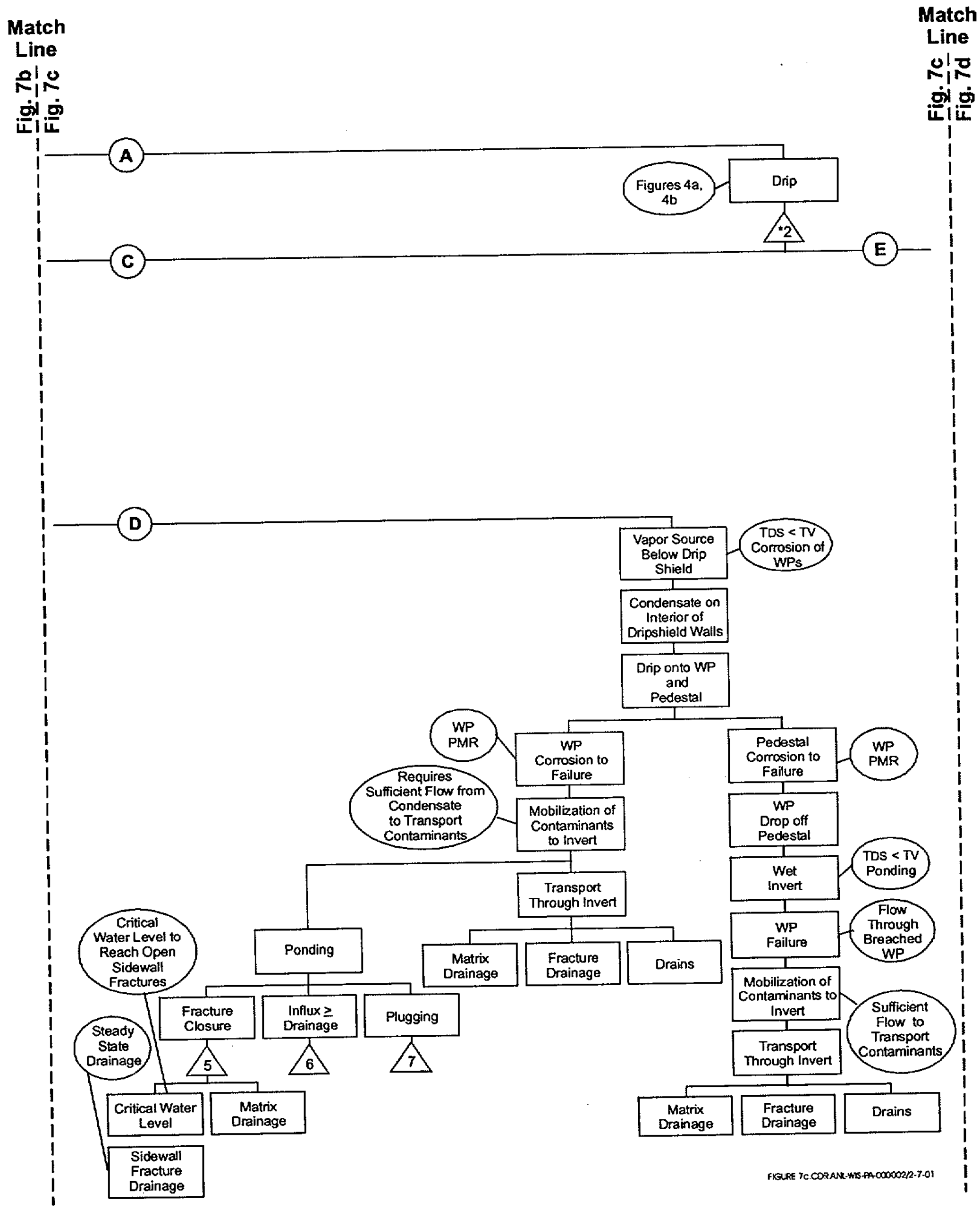

Figure 7c. Part 7c of Figure 7
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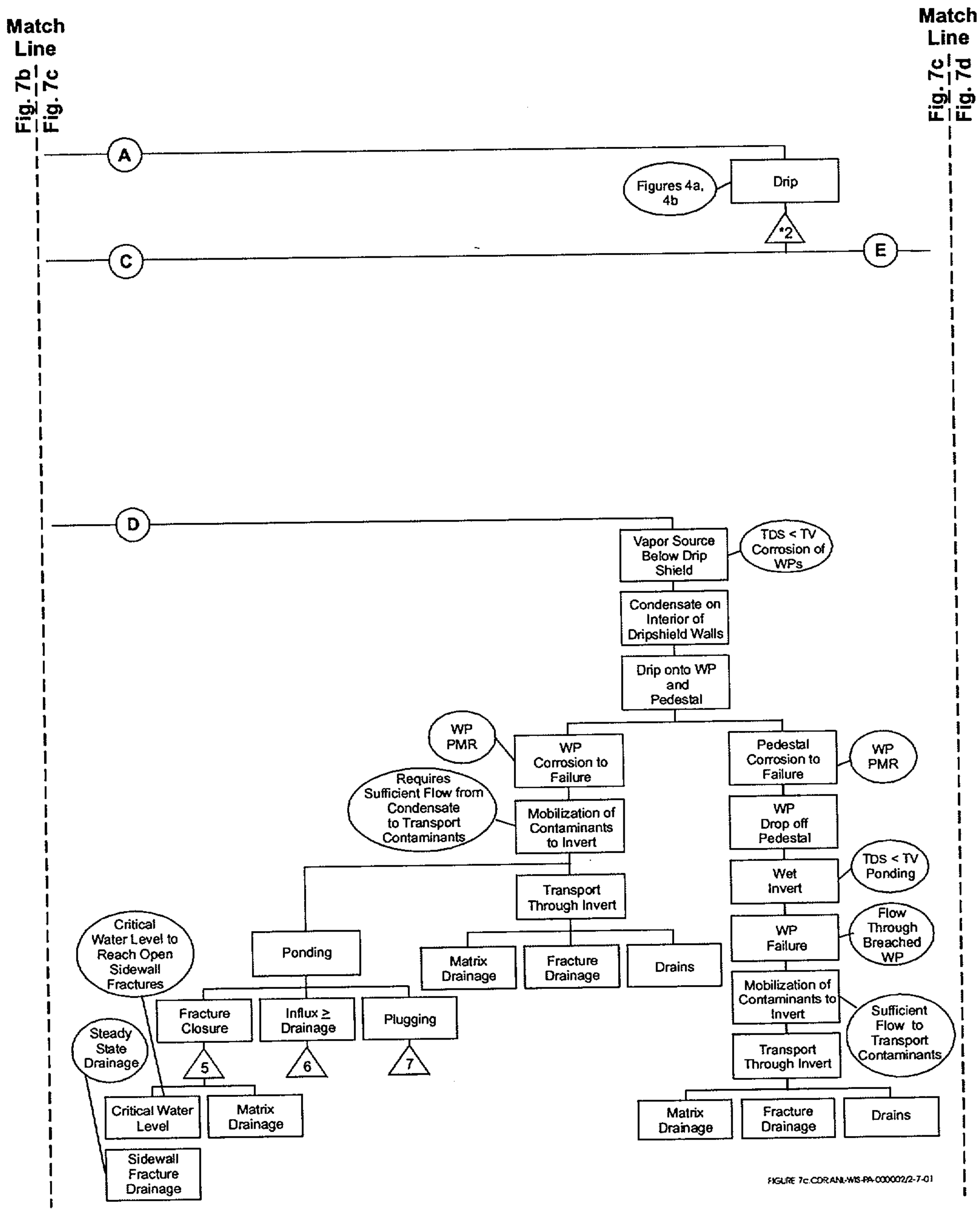

Figure 7A-c. (Backfill Option) Part 7A-c of Figure 7A
(See Legend in Figure 7A-f)

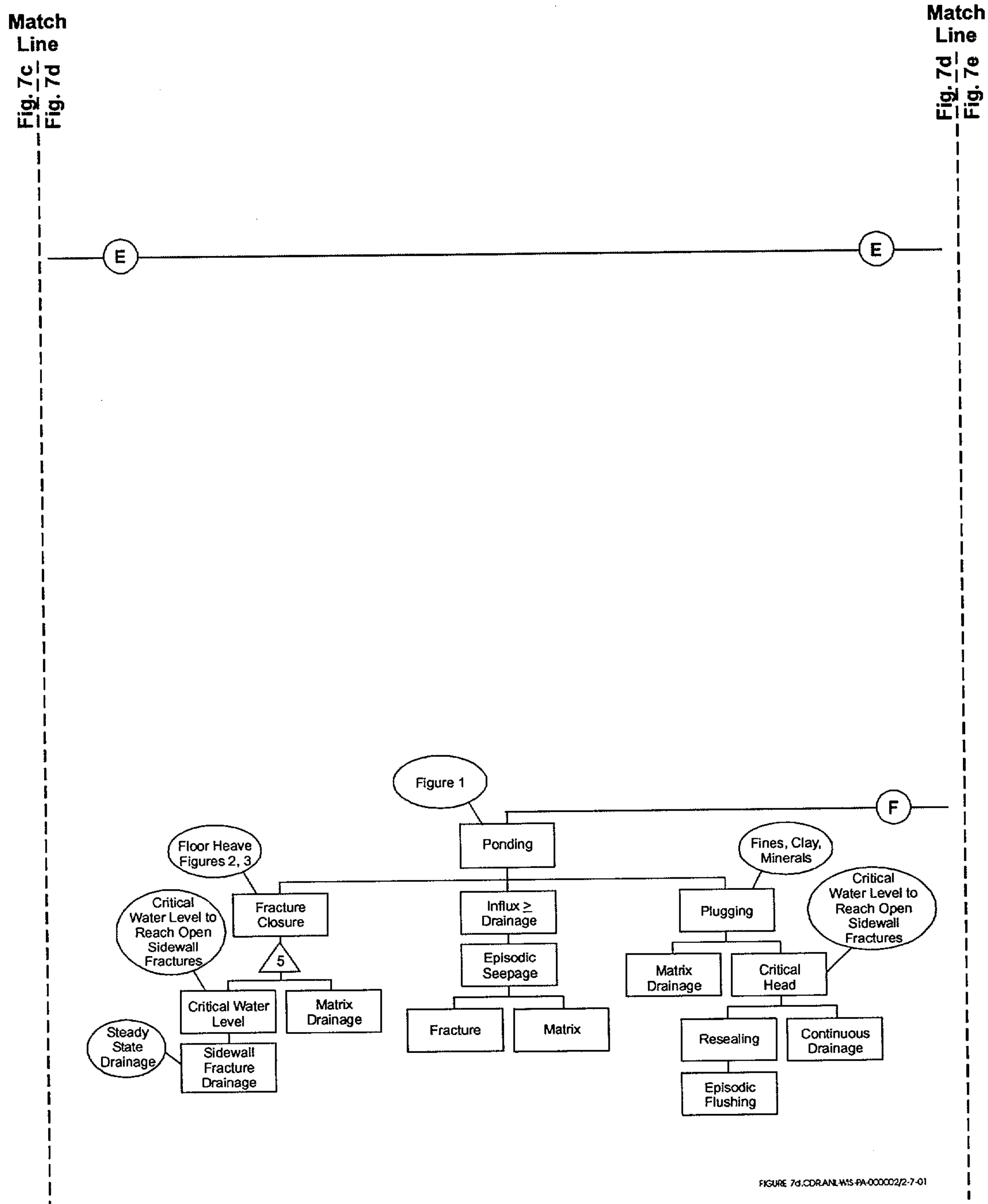

Figure 7d. Part 7d of Figure 7
(See Legend in Figure 7f)

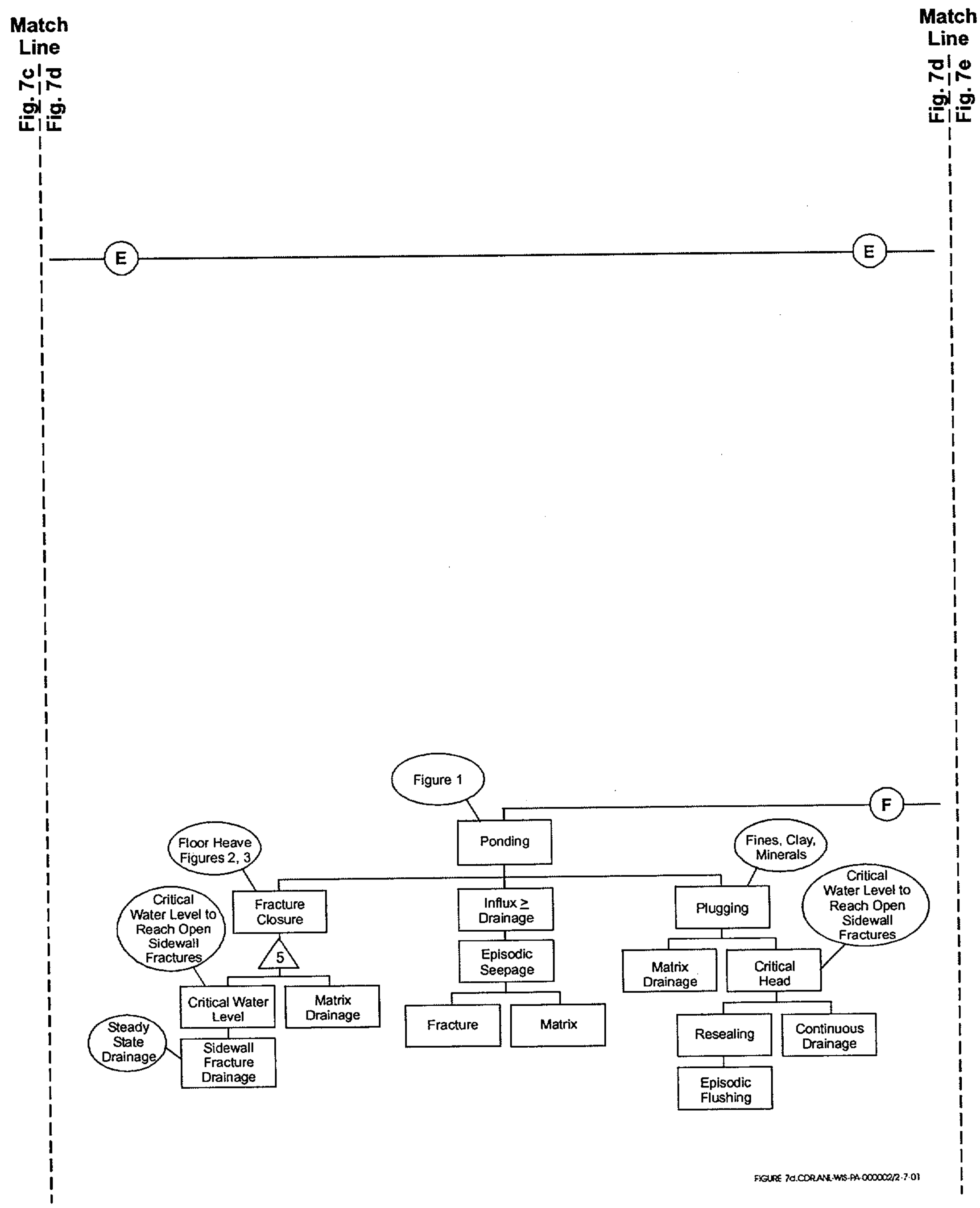

Figure 7A-d. (Backfill Option) Part 7A-d of Figure 7A
(See Legend in Figure 7A-f)

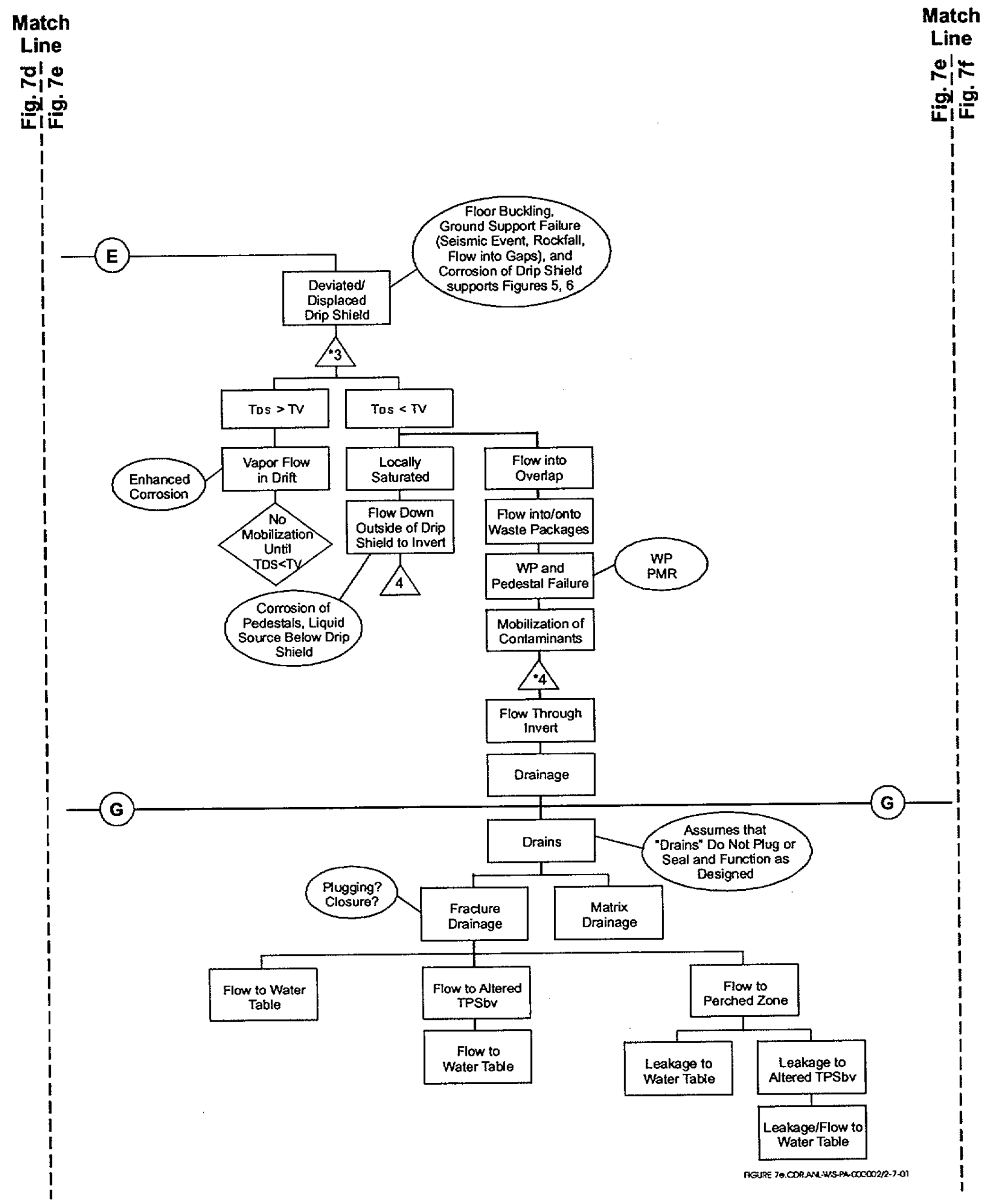

Figure 7e. Part 7e of Figure 7
(See Legend in Figure 7f)

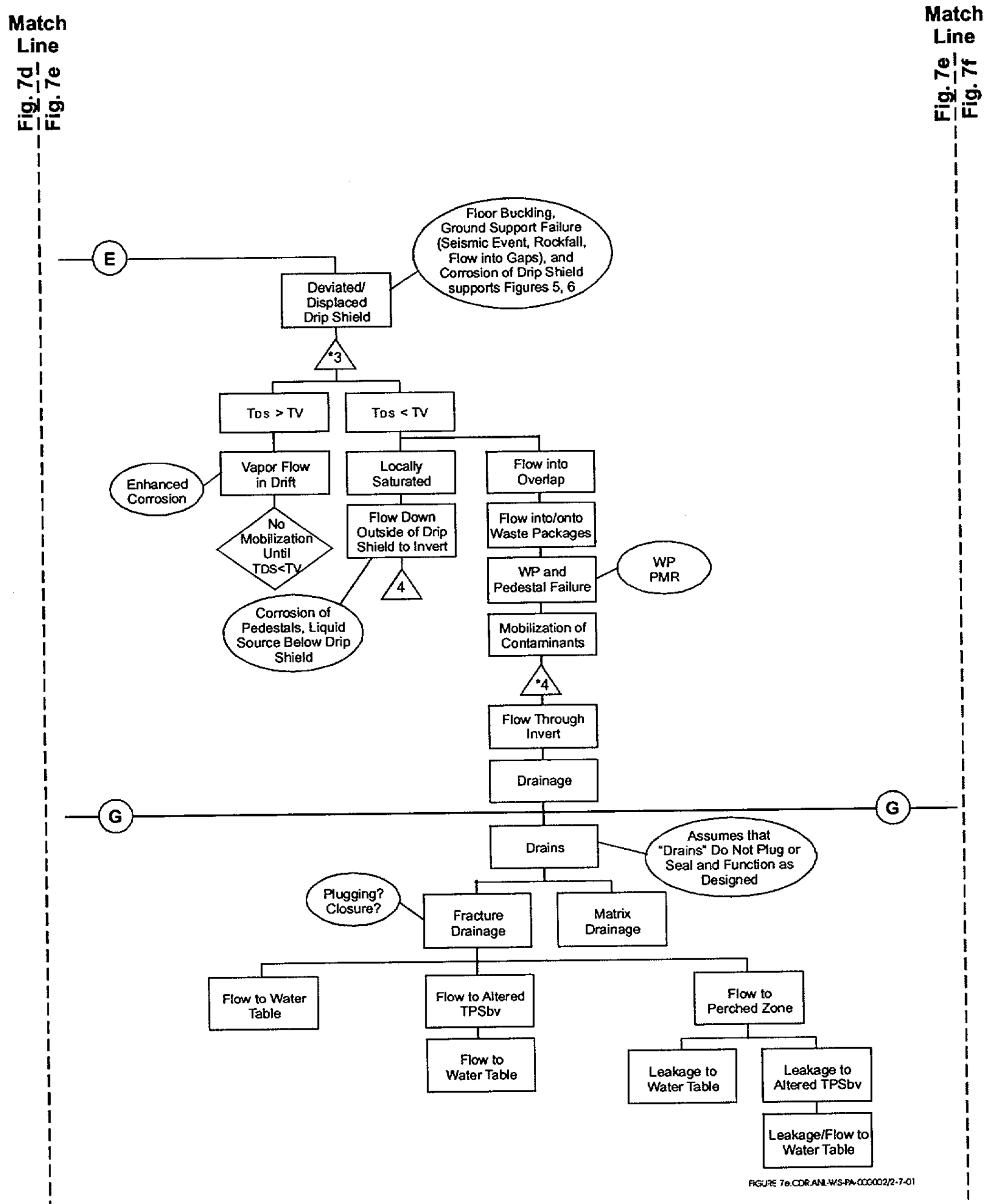

Figure 7A-e. (Backfill Option) Part 7A-e of Figure 7A
(See Legend in Figure 7A-f)

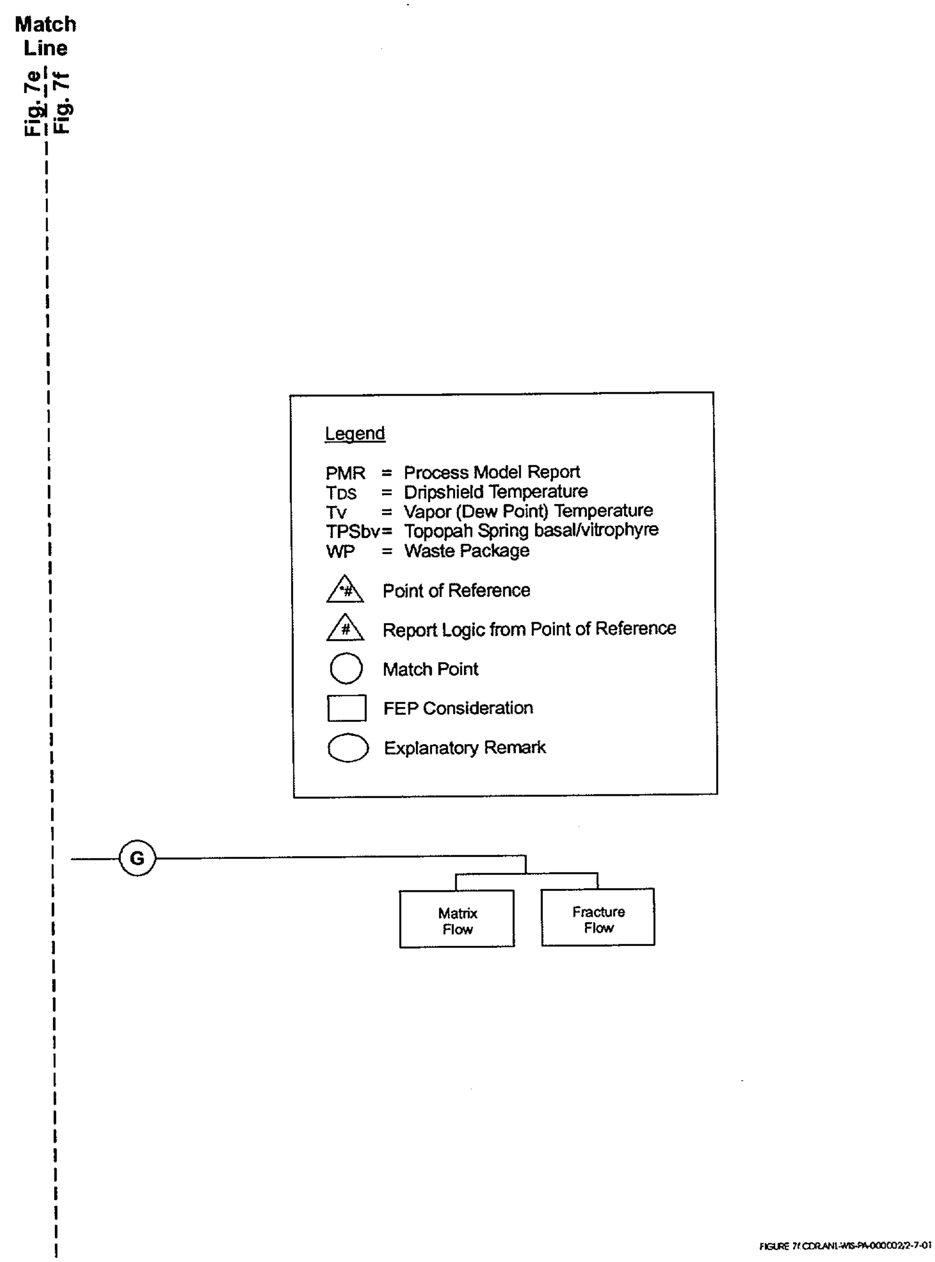

Figure 7f. Part 7f of Figure 7

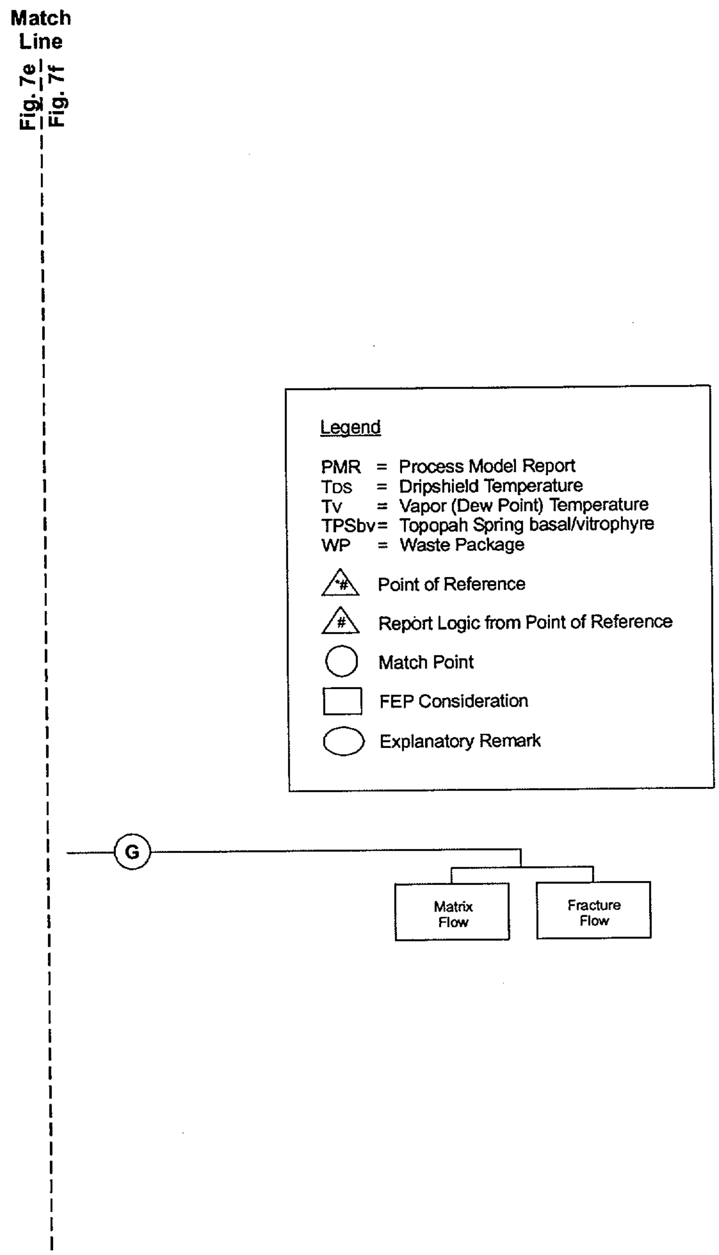

FIGURE 7f.CDR.ANL-WIS-PA-000002/2-7-01

Figure 7A-f. (Backfill Option) Part 7A-f of Figure 7A

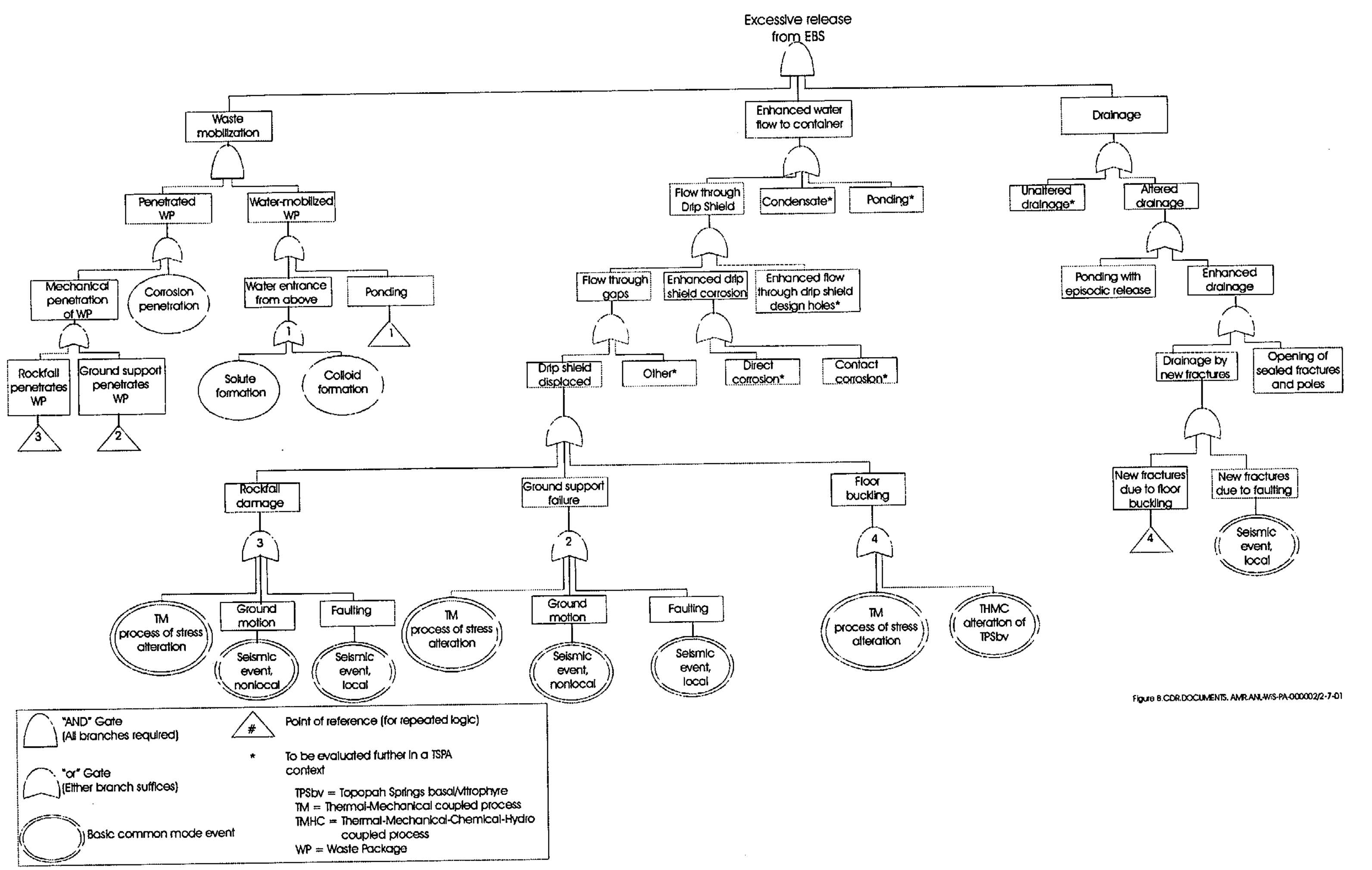

Figure 8. Common Cause Degradation Tree

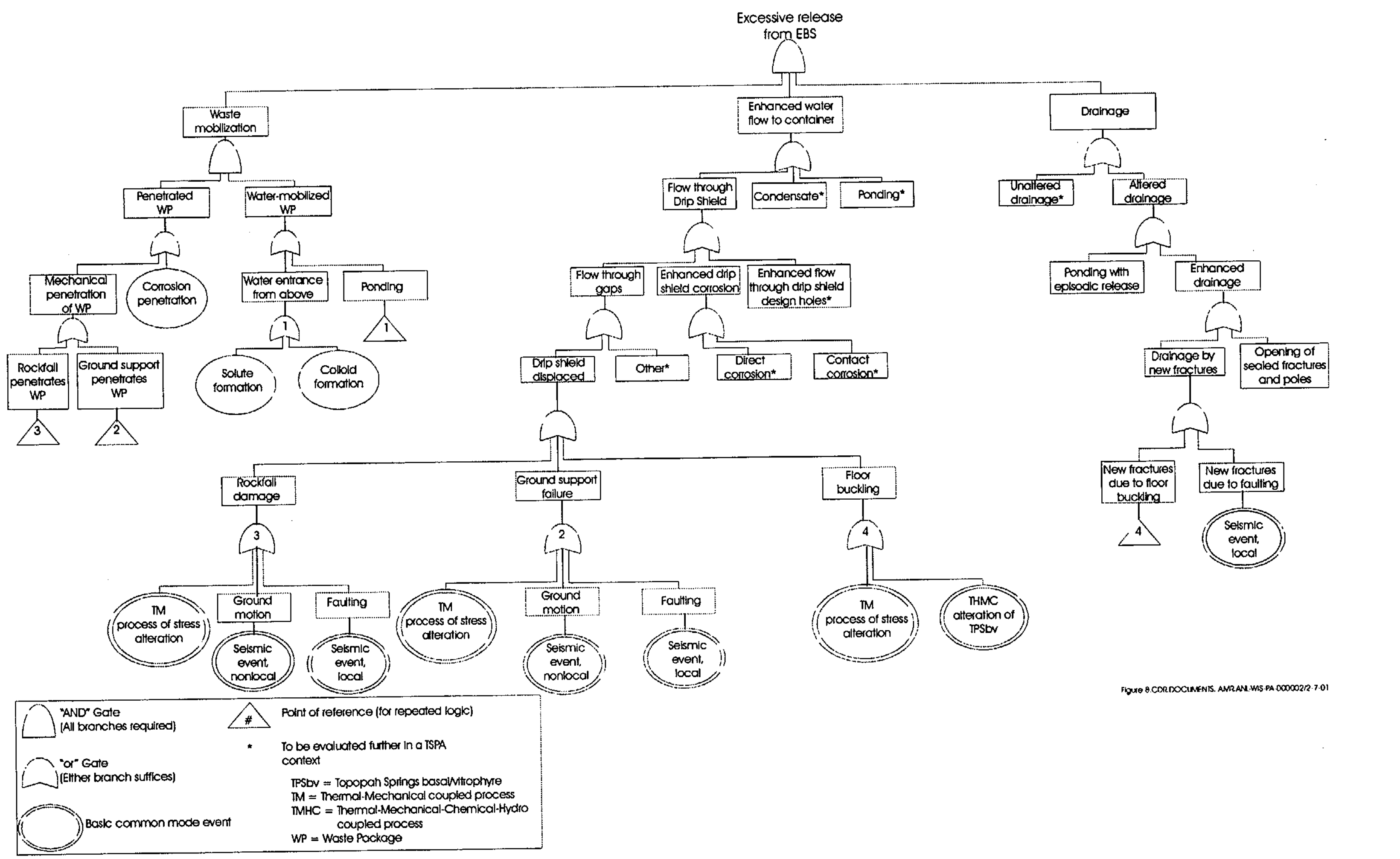

Figure 8A. (Backfill Option) Common Cause Degradation Tree

Table 1. EBS Primary Database FEPs

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
1	1.1.02.00.00	Excavation/ construction	This FEP is concerned with the effects associated with excavation/construction of the underground regions of the repository on the long-term behavior of the engineered and natural barriers. Excavation-related effects include changes to rock properties due to boring and blasting and chemical changes to the rock and incoming groundwater due to potential explosives residue. Excavation and other construction activities could also directly cause groundwater chemistry changes within the tunnel due to the impact of such contaminants as diesel exhaust, explosives residues, or other organic contaminants (Secondary FEP 1.1.02.00.03). Finally, oxidizing water introduced into the repository during excavation/construction could impact repository conditions/performance (Secondary FEP 1.1.02.00.04).	NFE, UZ
2	1.1.02.01.00	Site flooding (during construction and operation)	Flooding of the site during construction and operation could introduce water into the underground tunnels, which could affect the long-term performance of the repository. (Note that this is a specific example of an accident or unplanned event discussed under FEP 1.1.12.01.00.)	UZ
3	1.1.02.02.00	Effects of pre-closure ventilation	The duration of preclosure ventilation acts together with waste package spacing (as per design) to control the extent of the boiling front within the NFE.	NFE
4	1.1.02.03.00	Undesirable materials left	During construction and preclosure operation of the repository there might be possibilities for leaving unwanted material in the vicinity of the radioactive waste. These materials could be of different kinds and could to some extent affect many long-term processes in the repository from canister corrosion to transport mechanisms of radionuclides. (Note that this FEP has some overlap with the issues discussed under FEP 1.1.02.00.00.)	
5	1.1.03.01.00	Error in waste or backfill emplacement	Deviations from the design and/or errors in waste and backfill emplacement could affect long-term performance of the repository. A specific example of such an error that has been raised involves erroneously emplacing the waste packages in the saturated zone of the repository (Secondary FEP 1.1.03.01.04). This would clearly impact the repository performance both by impacting container corrosion and failure as well as by impacting radionuclide transport.	WP
6	1.1.07.00.00	Repository design	This category contains FEPs related to the design of the repository, and the ways in which the design contributes to long-term performance. Changes to or deviations from the specified design may affect the long-term performance of the disposal system.	SYS
7	1.1.08.00.00	Quality control	This category contains FEPs related to quality assurance and control procedures and tests during the design, construction, and operation of the repository, as well as the manufacture of the waste forms, containers, and engineered features. Lack of quality control could result in material defects, faulty waste package fabrication, and faulty or non-design-standard construction, all of which may lead to reduced effectiveness of the engineered barriers.	SYS

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
8	1.1.12.01.00	Accidents and unplanned events during operation	The long-term performance of the disposal system might be seriously affected by unplanned or improper activities that take place during construction, operation, and closure of the repository	SYS
9	1.1.13.00.00	Retrievability	This category contains FEPs related to design, emplacement, operational, or administrative measures that might be applied or considered in order to enable or ease retrieval of wastes. There may be a requirement to retrieve all or part of the waste stored in the repository (e.g., to recover valuable fissile materials or to replace defective containers.)	SYS
10	1.2.04.03.00	Igneous intrusion into repository	Magma from an igneous intrusion may flow into the drifts and extend over a portion of the repository site, forming a sill. The sill could be limited to the drifts or a continuous sill could form along the plane of the repository, bridging between adjacent drifts. Note that this FEP also encompasses FEP ebs # 36 from table 3 [from EBS FEP AMR Rev 00: "A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence."	DE
11	2.1.03.01.00	Corrosion of waste containers	Corrosion may contribute to waste package failure. Corrosion is most likely to occur at locations where water drips on the waste packages, but other mechanisms should be considered.	WP
12	2.1.03.10.00	Container healing	Pits and holes in waste packages could be partially or fully plugged by chemical or physical reactions during or after their formation, affecting corrosion processes and water flow and radionuclide transport through the breached container. Passivation by corrosion products is a potential mechanism for container healing.	WP
13	2.1.03.12.00	Container failure (long-term)	Waste packages and drip shields have a potential to fail over long periods of time by a variety of mechanisms, including general corrosion, stress corrosion cracking, pit corrosion, hydride cracking, microbially-mediated corrosion, internal corrosion, and mechanical impacts.	WP
14	2.1.04.01.00	Preferential pathways in the backfill	Preferential pathways for flow and diffusion may exist within the backfill and may affect long-term performance of the waste packages. Backfill may not preclude hydrological, chemical, and thermal interactions between waste packages within a drift.	
15	2.1.04.02.00	Physical and chemical properties of backfill	The physical and chemical properties of the backfill may affect groundwater flow, waste package and drip shield durability, and radionuclide transport in the waste disposal region. Note that this FEP also encompasses FEP ebs # 5 from table 3 [EBS FEP AMR Rev00, see FEP 2.1.06.05.00].	
16	2.1.04.03.00	Erosion or dissolution of backfill	Solid material in buffer or backfill is carried away by flowing groundwater, either by erosion of particulate matter or by dissolution. Note that this FEP also encompasses FEP ebs # 5 from table 3 [EBS FEP AMR Rev00, see FEP 2.1.06.05.00].	

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
17	2.1.04.04.00	Mechanical effects of backfill	Backfill may alter the mechanical evolution of the drift environment by providing resistance to rock creep and rock fall, by changing the thermal properties of the drift, or by other means. Impacts of the evolution of the properties of the backfill itself should be considered. Note that this FEP also encompasses FEP ebs # 5 from table 3[EBS FEP AMR Rev00, see FEP 2.1.06.05.00].	
18	2.1.04.05.00	Backfill evolution	Properties of the backfill may change through time, due to processes such as silica cementation, alteration of minerals, thermal effects, and physical compaction. These changes could then affect the movement of water and radionuclides in the backfill. Note that this FEP also encompasses FEP ebs # 5 from table 3 [EBS FEP AMR Rev00, see FEP 2.1.06.05.00].	
19	2.1.04.06.00	Properties of bentonite	This category contains FEPs specific to the properties of bentonite buffers. Because the Yucca Mountain design does not include bentonite backfill, all FEPs in this category are irrelevant to the YMP TSPA.	
20	2.1.04.07.00	Buffer characteristics	This category contains FEPs specific to repository designs that include chemical buffering agents in the waste disposal region. The Yucca Mountain design does not include buffering agents, and all FEPs in this category are irrelevant to the YMP TSPA	
21	2.1.04.08.00	Diffusion in backfill	Diffusion processes in backfill may affect waste package performance and radionuclide transport.	
22	2.1.04.09.00	Radionuclide transport through backfill	Radionuclide transport in the drift environment may be affected by the presence of backfill. Transport of both dissolved and colloidal species, advective and diffusive effects and sorption processes should be considered.	
23	2.1.06.01.00	Degradation of cementitious materials in drift	Degradation of cementitious material used for any purposes in the disposal region may affect long-term performance through both chemical and physical processes. Degradation may occur by physical, chemical, and microbial processes. Note that this FEP also encompasses FEPs ebs # 22 and 26 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.01.00, 2.1.06.02.00].	
24	2.1.06.02.00	Effects of rock reinforcement materials	Degradation of rock bolts, wire mesh, and other materials used in ground control may affect the long-term performance of the repository. Note that this FEP also encompasses FEPs ebs # 12, 21, 22, and 26 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.01.00, 2.1.06.02.00].	
25	2.1.06.03.00	Degradation of the liner	Degradation of materials used to line the drifts may occur by physical, chemical, or microbial processes, and may affect long-term performance.	
26	2.1.06.04.00	Flow through the liner	Groundwater flow may occur through the liner.	

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
27	2.1.06.05.00	Degradation of invert and pedestal	Degradation of the materials used in the invert and the pedestal supporting the waste package may occur by physical, chemical, or microbial processes, and may affect the long-term performance of the repository. Note that this FEP also encompasses FEPs ebs # 1, 5, 8, 9, and 11 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.06.00, 2.1.06.07.00, 2.1.07.01.00, 2.1.07.02.00]..	
28	2.1.06.06.00	Effects and degradation of drip shield	The drip shield will affect the amount of water reaching the waste package. Behavior of the drip shield in response to rockfall, ground motion, and physical, chemical degradation processes should be considered. Effects of the drip shield on the disposal region environment (for example, changes in relative humidity and temperature below the shield) should be considered for both intact and degraded conditions. Degradation processes specific to the chosen material should be identified and considered. For example, oxygen embrittlement should be considered for titanium drip shields. Note that this FEP also encompasses FEPs ebs # 2, 9, 10, 11, 15, 17, 19, 20, 24, 30, 31, and 32 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.05.00, 2.1.06.07.00, 2.1.07.01.00, 2.1.07.02.00].	WP
29	2.1.06.07.00	Effects at material interfaces	Physical and chemical effects that occur at the interfaces between materials in the drift, such as at the contact between the backfill and the drip shield, may affect the performance of the system. Note that this FEP also encompasses FEPs ebs # 9 and 11 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.05.00, 2.1.06.06.00, 2.1.07.01.00, 2.1.07.02.00].	WP
30	2.1.07.01.00	Rockfall (large block) WFClad— Rockfall	Rockfalls may occur that are large enough to mechanically tear or rupture waste package Note that this FEP also encompasses FEPs ebs # 6, 9, and 11 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.05.00, 2.1.06.06.00, 2.1.06.07.00, 2.1.07.02.00].	WP, WF Clad, WF Misc, DE
31	2.1.07.02.00	Mechanical degradation or collapse of drift	Partial or complete collapse of the drifts, as opposed to discrete rockfall, could occur as a result of seismic activity, thermal effects, stresses related to excavation, or possibly other mechanisms. Drift collapse could affect stability of the engineered barriers and waste packages. Drift collapse may be localized as stopping at faults or other geologic features. Rockfall of small blocks may produce rubble throughout part or all of the tunnel. Note that this FEP also encompasses FEPs ebs # 9, 11, and 37 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.05.00, 2.1.06.06.00, 2.1.06.07.00, 2.1.07.01.00].	DE

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
32	2.1.07.03.00	Movement of containers	Waste packages may move as a result of seismic activity, degradation of the invert or pedestal, rockfall, fault displacement, or other processes (See also FEP 2.1.06.05.00 - Degradation of Invert and Pedestal.) Note that this FEP also encompasses FEP ebs # 3 from table 3 [EBS FEP AMR Rev00, see FEP 2.1.07.03.00].	
33	2.1.07.04.00	Hydrostatic pressure on container	Waste packages emplaced in the saturated zone will be subjected to hydrostatic pressure in addition to stresses associated with the evolution of the waste and barrier system. This FEP is not relevant for the YMP design, which calls for emplacement in the	
34	2.1.07.05.00	Creeping of metallic materials in the EBS	Metals used in the waste package or drip shield may deform by creep processes in response to deviatoric stress.	WP
35	2.1.07.06.00	Floor buckling	Buckling, or heave, of the drift floor occurs in response to changing stress. Floor buckling may affect the performance of components of the EBS such as the drip shield, the invert, and the pedestal. Effects may include movement of EBS components, and changes in the topography of the surface of the drift floor and invert that may affect water flow. Note that this FEP also encompasses FEP ebs # 35 from table 3 [EBS FEP AMR Rev00, see FEP 2.1.07.06.00].	
36	2.1.08.01.00	Increased unsaturated water flux at the repository	An increase in the unsaturated water flux at the repository affects thermal, hydrological, chemical, and mechanical behavior of the system. Extremely rapid influx could reduce temperatures below the boiling point during part or all of the thermal period. Increases in flux could result from climate change, but the cause of the increase is not an essential part of the FEP.	NFE, UZ
37	2.1.08.02.00	Enhanced influx (Philip's drip)	An opening in unsaturated rock alters the hydraulic potential, affecting local saturation around the opening and redirecting flow. Some of the flow is directed to the opening where it is available to seep into the opening.	NFE, UZ
38	2.1.08.04.00	Cold traps	Emplacement of waste in drifts creates a large thermal gradient across the drifts. Moisture condenses on the roof and flows downward through the backfill.	
39	2.1.08.05.00	Flow through invert	The invert, a porous material consisting of crushed tuff, separates the waste package from the bottom of the tunnel (boundary to the UZ). Water may flow through the invert, either in its intact or degraded state, either in fractures or matrix porosity.	
40	2.1.08.06.00	Wicking in waste and EBS	Capillary rise, or wicking, is a potential mechanism for water to move through the waste and engineered barrier system.	

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
41	2.1.08.07.00	Pathways for unsaturated flow and transport in the waste and EBS	Unsaturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.	WF Misc
42	2.1.08.08.00	Induced hydrological changes in the waste and EBS	Thermal, chemical, and mechanical processes related to the construction of the repository and the emplacement of waste may induce changes in the hydrological behavior of the system. Note that this FEP also encompasses FEPs ebs # 13 and 14 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.08.08.00].	WF Misc
43	2.1.08.09.00	Saturated groundwater flow in waste and EBS	Saturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.	
44	2.1.08.11.00	Resaturation of repository	Water content in the repository will increase following the peak thermal period.	NFE
45	2.1.08.12.00	Drainage with Transport - Sealing and Plugging	Normal functioning of drainage in the drifts is not established, so how drainage will change if fractures are plugged is unclear. Suggestions include ponding until fractures in the wall are reached by the water level or until there is sufficient head to clear the fractures.	
46	2.1.08.13.00	Drains	Water accumulation in the drift would wet the invert materials, possibly pond, and provide a continuing source of water vapor beneath the drip shield and backfill for interaction with waste packages and their supports. Engineered drains are a consideration for mitigating such water accumulation and ponding.	
47	2.1.08.14.00	Condensation on Underside of Drip Shield	Condensation of water on the underside of drip shield affects waste package hydrologic and chemical environment.	
48	2.1.09.01.00	Properties of the potential carrier plume in the waste and EBS	When unsaturated flow in the drifts is re-established following the peak thermal period, water will have chemical and physical characteristics influenced by the near field host rock and EBS. Water chemistry may be strongly affected by interactions with cementitious materials.	NFE, WF Misc
49	2.1.09.02.00	Interaction with corrosion products	Corrosion products produced during degradation of the metallic portions of the EBS and waste package may affect the mobility of radionuclides. Sorption/desorption and coprecipitation/dissolution processes may occur. Note that this FEP also encompasses FEP ebs # 7 from table 3 [EBS FEP AMR Rev00, see FEP 2.1.09.02.00].	WF Misc
50	2.1.09.05.00	In-drift sorption; WF and in-package sorption.	Sorption of radionuclides within the waste and EBS may affect the aqueous concentrations of radionuclides released to the EBS.	WF Misc
51	2.1.09.06.00	Reduction-oxidation potential in waste and EBS	The redox potential in the waste and EBS influences the oxidation of barrier and waste-form materials and the solubility of radionuclide species. Local variations in the redox potential can occur.]	WF Misc
52	2.1.09.07.00	Reaction kinetics in waste and EBS	Chemical reactions, such as radionuclide dissolution/ precipitation reactions and reactions controlling the reduction-oxidation state, may not be equilibrium in the drift and waste environment.	WF Misc

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
53	2.1.09.08.00	Chemical gradients / enhanced diffusion in waste and EBS	The existence of chemical gradients within the disposal system, induced naturally or resulting from repository material and waste emplacement, may influence the transport of contaminants of dissolved and colloidal species. This could include, for example, diffusion in and through failed canisters.	WF Misc
54	2.1.09.11.00	Waste-rock contact	Waste and rock are placed in contact by mechanical failure of the drip shields and waste packages. Reactions between uranium, rock minerals, and water, in contact with both, precipitate uranium, leading spent fuel to dissolve more rapidly than if constrained by the equilibrium solubility of uranium.	WF Misc
55	2.1.09.12.00	Rind (altered zone) formation in waste, EBS, and adjacent rock	Thermo-chemical processes involving precipitation, condensation, and redissolution alter the properties of the waste, EBS, and the adjacent rock. These alterations may form a rind, or altered zone, in the rock, with hydrological, thermal, and mineralogical properties different from the current conditions.]	NFE, WF Misc
56	2.1.09.13.00	Complexation by organics in waste and EBS	The presence of organic complexants in water in the waste and EBS could augment radionuclide transport by providing a transport mechanism in addition to simple diffusion and advection of dissolved material. Organic complexants may include materials found in natural groundwater such as humates and fulvates, or materials introduced with the waste or engineered materials.	WF Misc
57	2.1.09.14.00	Colloid formation in waste and EBS	Colloids in the waste and EBS may affect radionuclide transport. Different types of colloids may exist initially or may form during the evolution of the system by a variety of mechanisms. This FEP aggregates all types of colloids into a single category. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00)	WF Col
58	2.1.09.15.00	Formation of true colloids in waste and EBS	True colloids are colloidal-size assemblages (between approximately one nanometer and 1 micrometer in diameter) of radionuclide-containing compounds. They may form in the waste and EBS during waste-form degradation and radionuclide transport. True colloids are also called radionuclide intrinsic colloids (or actinide intrinsic colloids, for those including actinide elements.)	WF Col

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
59	2.1.09.16.00	Formation of pseudo-colloids (natural) in waste and EBS	Pseudo-colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids include microbial colloids, mineral fragments, and humic and fulvic acids. This FEP addresses radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion. Pseudo-colloids formed from corrosion of the waste form and EBS are discussed in FEP 2.1.09.17.00. Microbial colloids are discussed in FEP 2.1.09.18.00.	WF Col
60	2.1.09.17.00	Formation of pseudo-colloids (corrosion products) in waste and EBS	Pseudo-colloids are colloidal sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids derived from corrosion products include microbial colloids, mineral fragments, and iron-oxide particles.	WF Col
61	2.1.09.18.00	Microbial colloid transport in the waste and EBS.	This FEP addresses the formation and transport of microbial colloids in the waste and EBS. Pseudo-colloids formed from corrosion and degradation of the metals in the waste form and EBS are discussed in FEP 2.1.09.16.00. Radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion are discussed in FEP 2.1.09.17.00.	WF Col
62	2.1.09.19.00	Colloid transport and sorption in the waste and EBS.	Interactions between radionuclide-bearing colloids and the waste and EBS may result in retardation of the colloids during transport by sorption mechanisms.	WF Col
63	2.1.09.20.00	Colloid filtration in the waste and EBS.	Filtration processes may affect transport of radionuclide-bearing colloids in the waste and EBS.	WF Col
64	2.1.09.21.00	Suspensions of particles larger than colloids	Groundwater flow through the waste could remove radionuclide-bearing particles by a rinse mechanism. Particles of radionuclide bearing material larger than colloids could then be transported in water flowing through the waste and EBS by suspension.	SZ, WF Col
65	2.1.10.01.00	Biological activity in waste and EBS	Biological activity in the waste and EBS may affect disposal-system performance by altering degradation processes such as corrosion of the waste packages and waste form (including cladding), by affecting radionuclide transport through the formation of colloids and biofilms, and by generating gases.	WP, WF Col
66	2.1.11.01.00	Heat output/ temperature in waste and EBS	Temperature in the waste and EBS will vary through time. Heat from radioactive decay will be the primary cause of temperature change, but other factors to be considered in determining the temperature history include the in-situ geothermal gradient, thermal properties of the rock, EBS, and waste materials, hydrological effects, and the possibility of exothermic reactions (see FEP 2.1.11.03.00). Considerations of the heat generated by radioactive decay should take different properties of different waste types, including DSNF, into account.	NFE, WF Misc

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
67	2.1.11.03.00	Exothermic Reactions and Other Thermal Effects in Waste Form and EBS	Exothermic reactions liberate heat and will alter the temperature of the disposal system and affect the properties of the repository and surrounding materials. Hydration of concrete used in the underground environment is an example of a possible exothermic reaction.	WF Misc
68	2.1.11.04.00	Temperature effects/coupled processes in waste and EBS	This FEP broadly encompasses all coupled-process effects of temperature changes within the waste and EBS. Technical discussions relevant to this FEP are provided individually for each relevant process. See FEP 2.1.11.01.00 for a discussion of the temperature history of repository. See FEP 2.1.11.03.00 for a discussion of possible exothermic reactions. See FEP 2.1.11.05.00 for a discussion of the effects of differential thermal expansion of repository components. See FEP 2.1.11.07.00 for a discussion of thermally-induced stresses in the waste and EBS. See FEP 2.1.11.08.00 for a discussion of thermal effects on chemical and microbial processes. See FEP 2.1.11.09.00 for a discussion of thermal effects on fluid flow in the waste and EBS. See 2.1.11.10.00 for a discussion of the Soret effect.	WF Misc
69	2.1.11.05.00	Differing thermal expansion of repository components	Thermally-induced stresses could alter the performance of the waste or EBS. For example, thermal stresses could create pathways for preferential fluid flow in the backfill or through the drip shield.	WP, WF Misc
70	2.1.11.07.00	Thermally-induced stress changes in waste and EBS	Thermally-induced stress changes in the waste and EBS may affect performance of the repository. Relevant processes include rockfall, drift stability, changes in physical properties of the disturbed rock zone around the repository, and changes in the physical properties of the surrounding rock.	WF Misc
71	2.1.11.08.00	Thermal effects: chemical and microbiological changes in the waste and EBS	Temperature changes may affect chemical and microbial processes in the waste and EBS. See FEP 2.1.10d for a discussion of microbial effects and subentries under 2.1.09 for a discussion of chemical effects.	WF Misc
72	2.1.11.09.00	Thermal effects on liquid or two-phase fluid flow in the waste and EBS	Temperature differentials may result in convective flow in the waste and EBS.	WF Misc
73	2.1.11.10.00	Thermal effects on diffusion (Soret effect) in waste and EBS	The Soret effect is a diffusion process caused by a thermal gradient. In liquids having both light and heavy molecules (or ions), the heavier molecules tend to concentrate in the cold region. Temperature differences in the waste and EBS may result in a component of diffusive solute flux that is proportional to the temperature gradient.	WF Misc

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
74	2.1.12.01.00	Gas generation	Gas may be generated in the repository by a variety of mechanisms. Gas generation might lead to pressurization of the repository, produce multiphase flow, and affect radionuclide transport. This FEP aggregates all types of gas generation into a single category. Technical discussions are presented separately for gas generation from fuel decay (FEP 2.1.12.02.00), corrosion (FEP 2.1.12.03.00), microbial degradation (FEP 2.1.12.04.00), concrete (FEP 2.1.12.02.05.00), radioactive gases within the waste (FEP 2.1.12.07.00), and radiolysis (2.1.13.01.00).	WF Misc
75	2.1.12.02.00	Gas generation (He) from fuel decay	Helium (He) gas production may occur by alpha decay in the fuel. He production might cause local pressure buildup in cracks in the fuel and in the void between fuel and cladding, leading to cladding failure.	WF Misc
76	2.1.12.03.00	Gas generation (H2) from metal corrosion	Gas generation can affect the mechanical behavior of the host rock and engineered barriers, chemical conditions, and brine flow, and, as a result, the transport of radionuclides. Gas generation due to oxic corrosion of waste containers, cladding, and/or structural materials will occur at early times following closure of the repository. Anoxic corrosion may follow the oxic phase, if all oxygen is depleted. The formation of a gas phase around the canister may even exclude water from the iron, thus inhibiting further corrosion.	WP, WF Misc
77	2.1.12.04.00	Gas generation (CO2, CH4, H2S) from microbial degradation	Microbial breakdown of cellulosic material, and possibly plastics and other synthetic materials, will produce mainly CO2, but also other gases. The rate of microbial gas production will depend upon the nature of the microbial populations established, the prevailing conditions (temperature, pressure, geochemical conditions), and the substrates present.	WF Misc
78	2.1.12.05.00	Gas generation from concrete	Production of gases from the aging and degradation of concrete may occur through radiolysis of water in the cement pore spaces and microbial growth on concrete.	
79	2.1.12.06.00	Gas transport in waste and EBS	Gas in the waste and engineered barrier system could affect the long-term performance of the disposal system. Radionuclides may be transported as dissolved gases or in gas bubbles. These may affect flow paths, and two-phase flow conditions may be important.	WF Misc
80	2.1.12.07.00	Radioactive gases in waste and EBS	Radioactive gases may exist or be produced in the repository. These gases may subsequently escape from the repository. Typical radioactive gases include 14-C (in 14CO2 and 14CH4) produced during microbial degradation, tritium, fission gases (Ar, Xe, Kr), and radon.	WF Misc
81	2.1.12.08.00	Gas explosions	Explosive gas mixtures could collect in the sealed repository. An explosion in the repository could have radiological consequences if the structure of the repository were damaged or near-field processes enhanced or inhibited.	WF Misc

Table 1. EBS Primary Database FEPs (Continued)

#	YM FEP Database FEP #	FEP NAME	YM FEP Database Rev 00 Primary FEP Description (for EBS)	Other PMRs
82	2.1.13.01.00	Radiolysis	Alpha, beta, gamma and neutron irradiation of water can cause disassociation of molecules, leading to gas production and changes in chemical conditions (Eh, pH, concentration of reactive radicals).]	WP, WF Misc
83	2.1.13.02.00	Radiation damage in waste and EBS	Strong radiation fields could lead to radiation damage to the waste forms and containers (CSNF, DSNF, DHLW), backfill, drip shield, seals and surrounding rock.	WP, WF Misc
84	2.1.13.03.00	Mutation	Radiation fields could cause mutation of microorganisms, leading to unexpected chemical reactions and impacts.]	WF Col WF Misc
85	2.2.01.04.00	Elemental solubility in excavation disturbed zone	Radionuclide solubility limits in the excavation-disturbed zone may differ from those in the waste and EBS.	
86	2.2.07.06.00	Episodic/ pulse release from repository	Episodic release of radionuclides from the repository and radionuclide transport in the UZ may occur both because of episodic flow into the repository, and because of other factors including intermittent failures of waste packages. Note that this FEP also encompasses FEP ebs # 16 from table 3 [see EBS FEP AMR Rev00, table did not transfer, see FEP 2.2.07.06.00].	UZ
87	2.2.08.04.00	Redissolution of precipitates directs more corrosive fluids to containers	Redissolution of precipitates that have plugged pores as a result of evaporation of groundwater in the hot zone, produces a pulse of fluid reaching the waste containers when gravity-driven flow resumes, which is more corrosive than the original fluid in the rock.	NFE, UZ
88	2.2.11.02.00	Gas pressure effects	Pressure variations due to gas generation may affect flow patterns and contaminant transport in the geosphere.	UZ

Table 2. Basis for EBS FEPs Identification

	Process Categories	Significant Potential Processes	Remarks
1.	Flow Types	Weeps	Locally-saturated flow, presumed to be fracture flow
		Drip	Water drops from the drift crown or fracture openings
		Matrix flow	Classical unsaturated flow through the matrix (Richard's equation.)
2.	Water Sources	Infiltrate	Fracture and matrix flow of water entering from the surface
		Condensate (including the effects of in-drift cold traps)	Condensate formed in rock and in drift, accumulated because of thermal-hydrologic processes
		Condensate under the Drip Shield (DS)	Condensation of water vapor beneath the drip shield from water in the invert
3.	Chemistry	Rock/water interactions for condensate	Alters solutes for corrosion processes
		Rock/water interactions for infiltrate	Alters solutes for corrosion processes
		Rock/water interactions for waste package effluent	Interaction of dissolved and colloidal contaminants with invert and drift floor for transport
		Rock/water interactions of fines and minerals in fractures along flow pathways	Interactions may plug fractures
		Colloids	Stability in the invert, filtration and alteration in the exit transport
4.	Heat	Thermo-mechanical interaction, stress -evolution	Rotation of least principal stress, fracture closure, thermal expansion of rock, residual drift size
		Thermo-chemical interaction, transport and sorption	Temperature rate and phase dependencies
		Thermo-chemical interaction, corrosion of ground support, pedestals, rails, etc.	Temperature rate dependencies
5.	Drift Alteration	Floor heave (buckling)	Buckling due to mechanical stress relief and to thermo-mechanical coupling
		Ground support failure	Failure due to mechanical stress relief and thermo-mechanical coupling
		Rockfall	
		Stopping up fracture zones	Localized rockfall affecting water intrusion
		Invert movement	Associated with floor and wall movement

Table 2. Basis for EBS FEPs Identification (Continued)

	Process Categories	Significant Potential Processes	Remarks
6.	Pathways	Infiltrate entering the EBS	Fracture and matrix flow of surface water
		Condensate entering the EBS	Condensate in the rock and in the drift provides a local water source.
		Movement around the drip shield	Drip shield functions as designed
		Movement through the drip shield	Drip shield fails in some locations
		Movement under the drip shield in the invert	Condensate flows along drip shield inner wall and drips
		Movement through the invert	Water chemistry changes, affects consequences of ponding.
		Flow/transport exiting in open fractures	Fracture exits in the drift floor
		Flow/transport exiting in plugged fractures	Fracture exits are plugged by fines, clays, mineral alterations, etc.
		Flow/transport exiting as matrix flow	Idealized transport in porous media.
7.	Corrosion	Chemical properties of infiltrate and condensate	Rock/water interactions would be expected to provide different water constituents for these different sources.
		Corrosion of the drip shield	Direct corrosion (water contact) and contact corrosion (with waste packages or rails).
		Corrosion of pedestals	Pedestal failure puts waste package on or in invert.
		Corrosion of ground support	Failure of rockbolts, wire mesh, and steel sets affects drift stability.
8.	Mobilization of Contaminants	Fuel/waste form effects on mobilization	Effects on solubility, speciation, colloid formation, stability
		Interaction with invert	Alteration of solute phases, sorption
		Interaction with drift floor	Alteration of solute phases, sorption
		Interaction with fractures and fracture plugging	Mineral alterations (e.g., reaction with fines), possible ponding
9.	Transport	Through invert	Alteration of solute phases, sorption
		Along drift floor	Alteration of solute phases, sorption
		Through drift floor	Fracture and matrix flow/transport including plugging
		Ponding and localization of flow	Ponding, episodic release, solubility limited transport

Table 2. Basis for EBS FEPs Identification (Continued)

	Process Categories	Significant Potential Processes	Remarks
10.	Ventilation	Mine – water removal/dryout	Establishes initial conditions
		Mine – heat removal	Establishes initial conditions
		Mountain – Background	Heat driven – postclosure affects temperature, moisture, exchange with atmosphere
		Mountain – Chimney effects	Chimney behavior of fault zones
11.	Seals	Ramps	Not in the waste emplacement drifts
		Shafts	Undefined in the EBS
		Drifts	Undefined purpose
12.	Drains	Location	Floor, lower ribs
		Design	Rock filled, intercepts likely locations of stress-relief fractures
		Functional lifetime	Probably not needed during the thermal period (no liquid water)
		Plugging and other failure modes	Thermo-mechanical compression, fines, mineralogical changes

Table 3. EBS FEPs Reference Figures

FEPs	FIGURES	
	Baseline Design	**Backfill Design Option**
FEATURES: All of the principal components of the EBS except some ground support elements.	1 through 6	1A through 6A
EVENTS: Rockfall	1 through 6	1A through 6A
PROCESSES:		
Condensate zone formation	1, 2	1A, 2A
Dryout	1, 2	1A, 2A
Floor buckling	1, 2	1A, 2A
Condensation		
In drift	1 through 6	1A through 6A
Beneath drip shield	3, 4, 5, 6	3A, 4A, 5A, 6A
Flow along drip shield wall		
Outside	3, 4, 5, 6	3A, 4A, 5A, 6A
Inside	3, 4, 6	3A, 4A, 6A
Flow through backfill (if used)		
Unsaturated zone/ saturated zone flow along DS		1A through 6A
Unsaturated zone/ saturated zone flow through backfill		3A, 4A, 5A, 6A
Drip Shield (DS) movement relative to waste packages/rails	1, 2	1A, 2A
Flow of fluid through gaps and separations in DS	1, 2	1A, 2A
Flow of backfill (if used) into gaps and separations in DS		
Unsaturated zone flow in relocated backfill		1A, 2A
Saturated zone flow through openings		1A, 2A
Drainage		
Through invert	3, 4, 5, 6	3A, 4A, 5A, 6A
Through drift floor	1, 2, 3, 4, 5, 6	1A through 6A
Through drift walls	1, 2	1A, 2A
Matrix and Fracture flows	6	6A

Table 4. Independently Identified EBS FEPs

FEP ebs #	FEP Name	Description	Considerations for Inclusion in TSPA
1	Pedestal Collapse	The waste package, as a result of pedestal collapse, lies on or in the invert and could be in contact with the drip shield and the rails, and be exposed to contact corrosion. While bedded in the invert, the waste package is more likely to see local ponding and the enhanced corrosion and mobilization which might accompany it.	Pedestal collapse could result from corrosion, seismically produced ground motion, or thermo-mechanical stress adjustment of the drift. It is an expected event in the repository life.
2	Drip Shield	Liquid water contact with the waste package is believed to affect the rate of corrosion of the metals, exposing the waste. The drip shield is intended to reduce direct liquid contact with the containers.	This feature is a baseline design feature (Wilkins and Heath 1999). It is intended to reduce direct contact of liquids with the waste package.
3	Drip Shield Supports	Failure of the drip shield supports allows the drip shield to make contact with the waste package or with the rails. Since the drip shield is made of Ti, the rails of steel, and the waste packages of a high-nickel alloy, contact could result in contact corrosion possibly affecting the integrity of the waste package.	Drip shield supports are part of the Engineered Barrier System design and their long-term failure must be considered.
4	Backfill (if used)	Crushed rock is placed to protect the waste package, or the drip shield and waste package from rockfall, failure of ground support, and possibly as a Richard's barrier for flow. Location of backfill, the size, and material type, all affect water chemistry (and the corrosion rates for drip shield and waste packages, dissolution rates for waste), and thermal properties (and waste temperatures and cladding failure). Suggestions for material type currently include sand, crushed limestone, marble, and crushed tuff. The last is the subject of investigation.	Backfill is a design feature which affects waste package lifetime, cladding failure, waste mobilization, and contaminant transport both indirectly (e.g., temperature) and directly (e.g., water chemistry). It is part of the disposal system and must be accounted for in some respect.
5	Invert	The invert materials, currently expected to be crushed rock, form the bed for the rails and will be the resting place for the waste package after the support pedestals fail. The invert is part of the flow pathway from the waste to the drift bottom and exit from the drift. The invert is also part of the flow pathway for water deflected by the drip shield from the waste packages. Water can accumulate in the invert, acting as a water vapor source for corrosion or possibly ponding. Accordingly, invert materials affect water chemistry for transport.	The invert is a design feature. It forms part of the flow pathway for liquid flow and for liquid transport, and its properties, affect water chemistry for transport. It forms part of the analysis of transport.
6	Rockfall Loading Distortion of Drip Shield	Contact corrosion, compromising the drip shield or the waste package develops as a result of displacement or distortion of the drip shield.	Enhanced corrosion would shorten the waste package life. Corrosion mechanisms need to be examined to establish their relative importance to waste package lifetime.
7	Rails	Rails (for WP emplacement, drip shield support, etc.) represent a material, steel, added to the repository which is not necessary to long-term isolation, but which may have an impact on corrosion of the drip shield and on water chemistry for transport. If the Ti drip shield and the steel rails are in contact, contact corrosion is expected, which could affect the long-term ability of the drip shield to divert water from the waste package. Such contact would be expected locally as a result of a seismic disturbance, rockfall, or ground support failure.	Rails represent an added material whose presence directly affects another component, the drip shield, and indirectly affects water chemistry. These interactions need to be included in accounting for the waste package environment.

Table 4. Independently Identified EBS FEPs (Continued)

FEP ebs #	FEP Name	Description	Considerations for Inclusion in TSPA
8	Pedestal	The pedestal may be distorted or crack because of floor heave (thermo-mechanical stress adjustment) and ground motion (seismic event), or may fail due to corrosion. Failure by any mode will drop the waste package onto or into the invert.	The pedestal is a design feature. Its lifetime and performance influence corrosion of the waste package. The pedestal needs to be accounted for or discounted in analyses.
9	Ground Motion	Ground motion, generated by seismic events, provides accelerations to components of the repository, including the waste packages, drip shield, backfill (if used), surrounding rock, and ground support. These accelerations cause relative motion of the components and could generate ground support failure, rockfall, and damage to waste packages and drip shields.	Ground motion is an expected phenomenon and is considered in the baseline design of both underground and surface components. Seismic hazard assessment is tasked to provide standard earthquake engineering inputs to support design.
10	Drip Shield Movement Relative to Waste Packages/Rails	Contact of the Ti drip shield with the waste package or with the steel rails will cause contact corrosion. In the former case, corrosion of the waste package will be enhanced, while in the latter case, that of the drip shield will be accelerated. Presumably, the fate of the rails is inconsequential.	Rockfall is expected to occur over the life of the repository. Some of that rockfall could be massive enough to cause displacement of the drip shield. The lifetimes of the waste packages are affected directly by corrosion or indirectly by reduced protection from the drip shield.
11	Relative Seismic Displacement	A seismic event in the potential repository generates relative displacements between waste package, drip shield, and rails, and ground support failure, and rockfall.	Since distant earthquakes producing local ground motion are assured events, the effects of such ground motion need to be accounted for in the EBS.
12	Ground Support Failure	Failure of ground support, for whatever reason, allows rockfall, displacement of backfill (if used) and waste packages, and development of new flow pathways. Possible cases include ground motion, thermo-mechanical stress adjustment and corrosion.	Ground support eventually fails. The rate of failure in a heated repository is unknown. Failure of ground support could initiate a chain of events which, by compromising the waste packages, allow early release.
13	Thermo-Mechanical Evolution of a Repository Block	Thermo-mechanical coupling, which alters the stress state of the rock surrounding the repository, affects floor buckling, fracture sealing and openings to the EBS, and loading and unloading of ground support.	Thermo-mechanical coupling which affects the flow of water into and out of the EBS directly alters the likelihood of contaminant transport.
14	Shear Fracture/ Fault Movement and Relaxation	Fractures that might otherwise be closed during the thermal period, because of compression from thermal expansion, are maintained as open pathways because of shear movement. Movement also allows distortion of the drift and the relative location of drip shield, rails, and waste packages, with possible contact being established.	Open fractures provide pathways for focus of water and release of contaminants, and need to be accounted for. Contact corrosion reduces drip shield and waste package performance.
15	Condensation Beneath Drip Shield	Condensation on the inner surface of the drip shield circumvents its performance and provides water to drip onto the waste package and its supporting pedestal. Enhanced corrosion of waste package and pedestal becomes possible.	The waste package and pedestal are not protected by the drip shield from this water source. The contribution to corrosion and mobilization of this source needs to be assessed.
16	Reflux Drainage of Condensate Zone	Condensate zones could contain a substantial amount of mobile water able to flow back into the drifts, perhaps as a single extended episode.	All water sources for significant amount of water reaching the EBS should be included in analyses.
17	Flow along Drip Shield (inside) Wall	Water vapor is available from water otherwise diverted from the waste packages, which flows down the drip shield and enters the invert, where it may accumulate.	The segmented drip shield is part of current baseline design. How it will work as engineered is subject to experimentation. Tests are presently in progress.

Table 4. Independently Identified EBS FEPs (Continued)

FEP ebs #	FEP Name	Description	Considerations for Inclusion in TSPA
18	Flow Through Backfill (if used)	Flow through the backfill reacts chemically with the backfill. This chemically altered water then interacts with the drip shield and rails to eventually reach the invert.	Flow through the backfill is likely to affect corrosion of the drip shield and, after reaction, also affect flow and transport exiting the drift.
19	Movement of Backfill (if used)Through Gaps and Separations in Drip Shield	The continuity of the drip shield and its ability to deflect liquid water could be compromised as a result of movement produced by thermo-mechanical or seismic processes.	Use of a drip shield requires some estimate of its behavior and confidence in that behavior.
20	Fluid Flow into Gaps and Separations in Drip Shield	The ability of the drip shield to deflect liquid water could be compromised as a result of the movement of liquid water through gaps or spaces which develop between drip shield segments.	Use of a drip shield requires some estimate of its behavior and confidence in that behavior.
21	Ground Support – Wire Mesh and Rockbolts	The expected life of ground support after the operational phase of the repository is unknown. Failure of ground support allows rockfall and development of a chimney or enlarged drift and filling of fracture or fault zones.	Failure of ground support is included; it is an expected phenomenon. All ground support fails eventually. The thermal environment of a repository puts the ground support under stress, which departs from the usual mine environment.
22	Ground Support – Rockbolts and Grout	The issues are that ground support introduces materials (Fe, grout, etc.) into the facility, which affects water chemistry. All ground support eventually fails, allowing rockfall, altering drift size and properties, and affecting flow pathways.	Introduced materials, such as steel rock bolts and grout, are expected to produce chemical changes in water chemistry. These changes may affect corrosion rates and will influence solubilities for contaminants. Failure of ground support, which allows rockfall and concomitant changes to drift geometry, affects the waste packages both directly by loading and indirectly by altering flow paths.
23	Drains (if used)	Water accumulation in the drift would wet the invert materials, possibly pond, and provide a continuing source of water vapor beneath the drip shield and backfill (if used) for interaction with waste packages and their supports.	Engineered drains are included for consideration. They are not currently part of the baseline design. Utility of a drain is not clear, because an engineered drain must survive the thermal period when presumably no water is available, and work properly after the thermal period is past. A drain which rapidly removes water reaching the drift floor, when prevention of waste package corrosion and mobilization of contaminants are the concerns, also rapidly removes contaminants from the drift once they are mobilized. Currently no trade-off studies are available.
24	Flow Along Drip Shield (outside) Wall	Since the segmented drip shield will see liquid water, the concerns are the effectiveness of the diversion (i.e., will liquid flow pass through the overlaps) and the corrosion resistance of the drip shield material to the water chemistry in the impinging water.	The segmented drip shield is part of current baseline design. How it will work as engineered, is subject to experimentation. Tests are presently in progress.

Table 4. Independently Identified EBS FEPs (Continued)

FEP ebs #	FEP Name	Description	Considerations for Inclusion in TSPA
25	Microbial Activity	The concern is microbially accelerated corrosion and mobilization occurring in the warm, moist environment of the EBS.	All mechanisms for corrosion and mobilization need to be assessed.
26	Rockbolt/Grout Corrosion	The corrosion and alteration changes the flow path for water entrance and alters the chemistry of the water following those flow paths.	Flow pathways control, in part, the rate and frequency of water entering a drift.
27	Drainage with Transport – Sealing and Plugging	Normal functioning of drainage in the drifts is not established, so how drainage will change if fractures are plugged is unclear. Suggestions include ponding until fractures in the wall are reached by the water level or until there is sufficient head to clear the fractures.	Engineered floor drains are included for consideration; they are not part of the baseline design (Wilkins and Heath 1999). Details of how contaminants leave the drift are important elements in establishing how transport proceeds through the unsaturated zone beneath the repository.
28	Drainage – Through Constructed Drains (not planned)	Water accumulation would be possible in a drift, particularly in a region of floor buckling, if normal drainage is blocked. Such blockage could occur if fines and debris are deposited in fractures or as sediment along the drift floor. Excess water could allow more rapid corrosion and contaminant mobilization. The conundrum here is that rapid draining of water sooner might also mean rapid draining of contaminated water later.	Engineered floor drains are included for consideration; they are not part of the baseline design (Wilkins and Heath 1999). Drainage, which is a component of the measure of the residence of contaminants in the drift, needs to be carefully examined to resolve the conundrum.
29	Drainage with Transport – Ponding	Water could accumulate in the invert in sufficient amounts to flood the waste package, enhancing corrosion and eventual mobilization. Criticality could be a possible consequence.	Any processes that accelerate corrosion and contaminant mobilization require careful attention. Here, the problem is that contaminants are not transported until they are moved out of the pond. Criticality calculations can be done for this simple geometry.
30	Drip Shield Corrosion – Flow of Backfill (if used) Through Corroded Elements	The continuity of the drip shield and its ability to deflect liquid water could be compromised as a result of holes produced by corrosion.	Use of a drip shield requires some estimate of its behavior and confidence in that behavior.
31	Drip Shield Corrosion – Fluid Flow Through Corroded Elements to Waste Packages	Deflection of liquid water away from the waste packages depends on continuity of the drip shield and the absence of penetrations.	Use of a drip shield requires some estimate of its behavior and confidence in that behavior.
32	Corrosion of Drip Shields and Waste Packages	Corrosion may contribute to waste package failure. Corrosion is most likely to occur at locations where water drips on the waste packages, but other mechanisms should be considered.	The time-dependent water distribution relative to waste package corrosion is an important parameter relative to repository performance.
33	Distal seismic event (Common-cause)	Local, disruptive ground motion is produced by an earthquake occurring outside the potential repository	See Section 6.2.5 and Table 5
34	Proximal seismic event (Common-cause)	Faulting or movement on an existing fault occurs through the potential repository	See Section 6.2.5 and Table 5
35	Thermo-chemical alteration of the Topopah Spring basal vitrophyre (Common-cause)	Thermo- chemical alteration of glasses to clays and zeolites, in this unit beneath the potential repository, accompanied by volume increases which appear at the nearest free surface, namely the drift floors.	See Section 6.2.5 and Table 5
36	Local igneous event (Common-cause)	A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence.	See Section 6.2.5 and Table 5
37	Thermo-mechanical stress alteration (Common-cause)	Stress alteration, increase, and relaxation during repository life causes massive failure of ground support, initiating a sequence of associated failures	See Section 6.2.5 and Table 5

Table 5. Summary of Common Cause Events Affecting the EBS

Common Mode	Description	Remarks
Distal seismic event (ebs33)	Local, disruptive ground motion is produced by an earthquake occurring outside the potential repository	Likelihood estimated in the Probabilistic Seismic Hazard Assessment (USGS 1998)
Proximal seismic event (ebs34)	Faulting or movement on an existing fault occurs through the potential repository	Likelihood estimated in the Probabilistic Seismic Hazard Assessment (USGS 1998)
Thermo-chemical alteration of the Topopah Spring basal vitrophyre (ebs35)	Thermo- chemical alteration of glasses to clays and zeolites, in this unit beneath the potential repository, accompanied by volume increases which appear at the nearest free surface, namely the drift floors.	Mechanism established experimentally and reported to the U.S. Department of Energy (DOE 1996a)
Local igneous event (ebs36)	A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence.	Likelihood estimated in Probabilistic Volcanic Hazards Assessment (CRWMS M&O 1996)
Thermo-mechanical stress alteration (ebs37)	Stress alteration, increase, and relaxation during repository life causes massive failure of ground support, initiating a sequence of associated failures	Unknown; thought to be limited by gradual and local failure of ground support

Table 6. Relationship of Independently Identified (ebs) FEPs to Database FEPs

FEP ebs #	FEP Name	Corresponding Primary Database FEP
1	Pedestal Collapse	2.1.06.05.00 – Degradation of Invert and Pedestal
2	Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield
3	Drip Shield Supports	2.1.07.03.00 – Movement of Containers (a)
4	Backfill	2.1.04.0x.00 – Five Backfill FEPs (b)
5	Invert	2.1.06.05.00 – Degradation of Invert and Pedestal
6	Rockfall Loading Distortion of Drip Shield	2.1.07.01.00 - Rockfall
7	Rails	2.1.09.02.00 – Interaction with Corrosion Products
8	Pedestal	2.1.06.05.00 – Degradation of Invert and Pedestal
9	Ground Motion	2.1.06.05.00 – Degradation of Invert and Pedestal (c) 2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.06.07.00 – Effects at Material Interfaces 2.1.07.01.00 – Rockfall 2.1.07.02.00 – Mechanical Degradation or Collapse of Drift
10	Drip Shield Movement Relative to Waste Packages/Rails	2.1.06.06.00 – Effects and Degradation of the Drip Shield
11	Relative Seismic Displacement	2.1.06.05.00 – Degradation of Invert and Pedestal (c) 2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.06.07.00 – Effects at Material Interfaces 2.1.07.01.00 – Rockfall 2.1.07.02.00 – Mechanical Degradation or Collapse of Drift
12	Ground Support Failure	2.1.06.02.00 – Effects of Rock Reinforcement Materials
13	Thermo-Mechanical Evolution of a Repository Block	2.1.08.08.00 – Induced Hydrological Changes in the Waste and EBS (d)
14	Shear Fracture/ Fault Movement and Relaxation	2.1.08.08.00 – Induced Hydrological Changes in the Waste and EBS (d) (also see ebs #11)
15	Condensation Beneath Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.08.14.00 - Condensation on Underside of Drip Shield
16	Reflux Drainage of Condensate Zone	2.2.07.06.00 – Episodic / Pulse Release from Repository
17	Flow along Drip Shield (inside) Wall	2.1.06.06.00 – Effects and Degradation of Drip Shield
18	Flow Through Backfill	2.1.04.01.00 – Preferential Pathways in the Backfill
19	Movement of Backfill Through Gaps and Separations in Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield
20	Fluid Flow into Gaps and Separations in Drip Shield	2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.08.04.00 – Cold Traps
21	Ground Support – Wire Mesh and Rockbolts	2.1.06.02.00 – Effects of Rock Reinforcement Materials
22	Ground Support – Rockbolts and Grout	2.1.06.01.00 – Degradation of Cementitious Materials in Drift 2.1.06.02.00 – Effects of Rock Reinforcement Materials
23	Drains (if used)	2.1.08.13.00 – Drains

24	Flow Along Drip Shield (outside) Wall	2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.08.04.00 – Cold Traps
25	Microbial Activity	2.1.10.01.00 – Biological Activity in Waste and EBS
26	Rockbolt/Grout Corrosion	2.1.06.01.00 – Degradation of Cementitious Materials in Drift (d) 2.1.06.02.00 – Effects of Rock Reinforcement Materials
27	Drainage with Transport – Sealing and Plugging	2.1.08.12.00 – Drainage With Transport, Sealing and Plugging (d)
28	Drainage – Through Constructed Drains	See ebs # 23
29	Drainage with Transport – Ponding	See ebs # 27
30	Drip Shield Corrosion – Flow of Backfill Through Corroded Elements	2.1.06.06.00 – Effects and Degradation of Drip Shield
31	Drip Shield Corrosion – Fluid Flow Through Corroded Elements to Waste Packages	2.1.06.06.00 – Effects and Degradation of Drip Shield 2.1.08.04.00 – Cold Traps
32	Corrosion of Drip Shields and Waste Packages	2.1.06.06.00 – Effects and Degradation of Drip Shield
33	Local, disruptive ground motion is produced by an earthquake occurring outside the potential repository	See database FEP 1.2.01.01.00 – Tectonic Activity – large scale, FEP 1.2.02.01.00 – Fractures, and FEP 1.2.03.01.00 – Seismicity for discussion of integrated effects (e). Specific effects within EBS are covered by FEPs above.
34	Faulting or movement on an existing fault occurs through the potential repository	See database FEP 1.2.01.01.00 – Tectonic Activity – large scale, FEP 1.2.02.01.00 – Fractures, and FEP 1.2.03.01.00 – Seismicity for discussion of integrated effects (e). Specific effects within EBS are covered by FEPs above.
35	Thermo- chemical alteration of glasses to clays and zeolites, in this unit beneath the potential repository, accompanied by volume increases which appear at the nearest free surface, namely the drift floors.	2.1.07.06.00 – Floor buckling
36	A basaltic intrusion intersects potential repository drifts and may reach the surface. EBS design and performance is of little significance for this occurrence.	1.2.04.03.00 – Igneous Intrusion
37	Stress alteration, increase, and relaxation during repository life causes massive failure of ground support, initiating a sequence of associated failures	2.1.07.02.00 – Mechanical Degradation or Collapse of Drift

(a) – actual WP corrosion due to drip shield contact with waste package is a WP issue
(b) – 5 primary FEPs are included in the database dealing with backfill
(c) – each of these FEPs is impacted by seismic events
(d) – effects occurring in the rock outside of the drift are considered in the NFE analysis and would be accounted for in the EBS analysis via inlet flow boundary conditions
(e) – these FEPs are not EBS specific and are not discussed herein

Table 7. Relevant Analysis Model Report Identification

AMR Title	AMR ID	Reference	Document ID Number
Invert Diffusion Properties Model	E0000	CRWMS M&O 2000a	ANL-EBS-MD-000031
Physical and Chemical Environment Abstraction Model	E0010	CRWMS M&O 2000b	ANL-EBS-MD-000046
Engineered Barrier System Features, Events, and Processes and Degradation Modes Analysis	E0015	CRWMS M&O 2000c	ANL-EBS-MD-000035
In-Drift Microbial Communities	E0040	CRWMS M&O 2000d	ANL-EBS-MD-000038
EBS Radionuclide Transport Model	E0050	CRWMS M&O 2000f	ANL-EBS-MD-000034
Ventilation Model	E0075	CRWMS M&O 2000g	ANL-EBS-MD-000030
Drift Degradation Analysis	E0080	CRWMS M&O 2000h	ANL-EBS-MD-000027
Water Distribution and Removal Model	E0090	CRWMS M&O 2000i	ANL-EBS-MD-000032
EBS Radionuclide Transport Abstraction	E0095	CRWMS M&O 2000j	ANL-WIS-PA-000001
Engineered Barrier System: Physical and Chemical Environment Model	E0100	CRWMS M&O 2000k	ANL-EBS-MD-000033
In-Drift Precipitates/Salts Analysis	E0105	CRWMS M&O 2000l	ANL-EBS-MD-000045
Multiscale Thermohydrologic Model	E0120	CRWMS M&O 2000m	ANL-EBS-MD-000049
Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux	E0130	CRWMS M&O 2000n	ANL-EBS-HS-000003
In-Package Chemistry Abstraction	F0170	CRWMS M&O 2000p	ANL-EBS-MD-000037

Table 8. Summary of EBS FEP Screening Decisions

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
1	1.1.02.00.00	Excavation/Construction	Excluded	Low Consequence	NFE, UZ
2	1.1.02.01.00	Site Flooding (During Construction and Operation)	Excluded	Low Consequence	UZ
3	1.1.02.02.00	Effects of Preclosure Ventilation	Included		NFE
4	1.1.02.03.00	Undesirable Materials Left	Excluded	Low Consequence	
5	1.1.03.01.00	Error in Waste or Backfill Emplacement	Excluded (high-consequence undetected errors) Excluded (other undetected errors)	Low Probability Low Consequence	WP
6	1.1.07.00.00	Repository Design	Included (other effects) Excluded (design deviations)	 Low Consequence	SYS
7	1.1.08.00.00	Quality Control	Included (specified defects and deviations) Excluded (other defects and deviations)	 Low Consequence	SYS
8	1.1.12.01.00	Accidents and Unplanned Events During Operation	Excluded	Low Consequence	SYS
9	1.1.13.00.00	Retrievability	Included		SYS
10	1.2.04.03.00	Igneous Intrusion into Repository	Included		DE
11	2.1.03.01.00	Corrosion of Waste Containers	Included		WP
12	2.1.03.10.00	Container Healing	Excluded	Low Consequence (3)	WP
13	2.1.03.12.00	Container Failure (Long-term)	Included		WP
14	2.1.04.01.00	Preferential Pathways in the Backfill (*)	Excluded (1)	Low Probability	
15	2.1.04.02.00	Physical and Chemical Properties of Backfill (*)	Excluded (1)	Low Probability	
16	2.1.04.03.00	Erosion or Dissolution of Backfill (*)	Excluded	Low Probability (2)	
17	2.1.04.04.00	Mechanical Effects of Backfill (*)	Excluded (1)	Low Probability	
18	2.1.04.05.00	Backfill Evolution (*)	Excluded (1)	Low Probability	
19	2.1.04.06.00	Properties of Bentonite (*)	Excluded	Low Probability	
20	2.1.04.07.00	Buffer Characteristics (*)	Excluded	Low Probability	
21	2.1.04.08.00	Diffusion in Backfill (*)	Excluded	Low Probability (2)	
22	2.1.04.09.00	Radionuclide Transport Through Backfill (*)	Excluded	Low Probability (2)	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
23	2.1.06.01.00	Degradation of Cementitious Materials in Drift	Included (drift degradation) Excluded (seepage chemistry)	Low Consequence	
24	2.1.06.02.00	Effects of Rock Reinforcement Materials	Included (drift degradation) Excluded (seepage chemistry)	Low Consequence	
25	2.1.06.03.00	Degradation of the Liner (*)	Excluded	Low Probability	
26	2.1.06.04.00	Flow Through the Liner (*)	Excluded	Low Probability	
27	2.1.06.05.00	Degradation of Invert and Pedestal	Included (pedestal) Excluded (invert)	Low Consequence	
28	2.1.06.06.00	Effects and Degradation of Drip Shield	Included		WP
29	2.1.06.07.00	Effects at Material Interfaces	Excluded	Low Consequence	WP
30	2.1.07.01.00	Rockfall (Large Block)	Excluded	Low Consequence	WP, DE, WF Clad, WF Misc
31	2.1.07.02.00	Mechanical Degradation or Collapse of Drift	Excluded	Low Consequence	DE
32	2.1.07.03.00	Movement of Containers	Included (contact with invert) Excluded (drip shield separation)	Low Consequence	
33	2.1.07.04.00	Hydrostatic Pressure on Container (*)	Excluded	Low Probability	
34	2.1.07.05.00	Creeping of Metallic Materials in the EBS	Excluded	Low Consequence	WP
35	2.1.07.06.00	Floor Buckling	Excluded	Low Consequence	
36	2.1.08.01.00	Increased Unsaturated Water Flux at the Repository	Included		NFE, UZ
37	2.1.08.02.00	Enhanced Influx (Philip's Drip)	Included		NFE, UZ
38	2.1.08.04.00	Cold Traps	Excluded	Low Consequence	
39	2.1.08.05.00	Flow Through Invert	Included		
40	2.1.08.06.00	Wicking in Waste and EBS	Included		
41	2.1.08.07.00	Pathways for Unsaturated Flow and Transport in the Waste and EBS	Included		WF Misc
42	2.1.08.08.00	Induced Hydrological Changes in the Waste and EBS	Included		WF Misc
43	2.1.08.09.00	Saturated Groundwater Flow in Waste and EBS	Excluded	Low Consequence	
44	2.1.08.11.00	Resaturation of Repository	Included		NFE
45	2.1.08.12.00	Drainage with Transport – Sealing and Plugging	Excluded	Low Consequence	
46	2.1.08.13.00	Drains (*)	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
47	2.1.08.14.00	Condensation on Underside of Drip Shield	Excluded	Low Consequence	
48	2.1.09.01.00	Properties of the Potential Carrier Plume in the Waste and EBS	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
49	2.1.09.02.00	Interaction with Corrosion Products	Included (colloids) Excluded (other effects)	Low Consequence	
50	2.1.09.05.00	In-drift Sorption	Excluded	Low Consequence (3)	NFE, WF Misc
51	2.1.09.06.00	Reduction-oxidation Potential in Waste and EBS	Included		WF Misc
52	2.1.09.07.00	Reaction Kinetics in Waste and EBS	Excluded	Low Consequence	WF Misc
53	2.1.09.08.00	Chemical Gradients/Enhanced Diffusion in Waste and EBS	Included (diffusion out WP and through invert) Excluded (within WF)	Low Consequence	WF Misc
54	2.1.09.11.00	Waste-Rock Contact	Excluded	Low Consequence	WF Misc
55	2.1.09.12.00	Rind (Altered Zone) Formation in Waste, EBS, and Adjacent Rock	Excluded	Low Consequence	WF Misc
56	2.1.09.13.00	Complexation by Organics in Waste and EBS	Excluded	Low Consequence	WF Misc
57	2.1.09.14.00	Colloid Formation in Waste and EBS	Included		NFE, WF Misc
58	2.1.09.15.00	Formation of True Colloids in Waste and EBS	Excluded	Low Consequence	WF Misc
59	2.1.09.16.00	Formation of Pseudo-colloids (natural) in Waste and EBS	Included		WF Col
60	2.1.09.17.00	Formation of Pseudo-colloids (corrosion products) in Waste and EBS	Included		WF Col
61	2.1.09.18.00	Microbial Colloid Transport in the Waste and EBS	Excluded	Low Consequence	WF Col
62	2.1.09.19.00	Colloid Transport and Sorption in the Waste and EBS	Included (transport) Excluded (sorption)	Low Consequence	WF Col
63	2.1.09.20.00	Colloid Filtration in the Waste and EBS	Excluded	Low Consequence	WF Col
64	2.1.09.21.00	Suspensions of Particles Larger than Colloids	Excluded	Low Consequence	WF Col
65	2.1.10.01.00	Biological Activity in Waste and EBS	Included (MIC) Excluded (other effects)	Low Consequence	WF Col
66	2.1.11.01.00	Heat Output / Temperature in Waste and EBS	Included (other effects) Excluded (exothermic reactions)	Low Consequence	SZ, WF Col

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
67	2.1.11.03.00	Exothermic Reactions in Waste and EBS	Excluded	Low Consequence	WP, WF Col
68	2.1.11.04.00	Temperature Effects / Coupled Processes in Waste and EBS	Included		NFE, WF Misc
69	2.1.11.05.00	Differing Thermal Expansion of Repository Components	Excluded	Low Consequence	WF Misc
70	2.1.11.07.00	Thermally-induced Stress Changes in Waste and EBS	Included		WF Misc
71	2.1.11.08.00	Thermal Effects: Chemical and Microbiological Changes in the Waste and EBS	Included		WP, WF Misc
72	2.1.11.09.00	Thermal Effects on Liquid or Two-phase Fluid Flow in the Waste and EBS	Included		WF Misc
73	2.1.11.10.00	Thermal Effects on Diffusion (Soret effect) in Waste and EBS	Excluded	Low Consequence	WF Misc
74	2.1.12.01.00	Gas Generation	Excluded	Low Consequence	WF Misc
75	2.1.12.02.00	Gas Generation (He) from Fuel Decay	Excluded	Low Consequence	WF Misc
76	2.1.12.03.00	Gas Generation (H_2) from Metal Corrosion	Excluded	Low Consequence	WF Misc
77	2.1.12.04.00	Gas Generation (CO_2, CH_4, H_2S) from Microbial Degradation	Excluded	Low Consequence	WF Misc
78	2.1.12.05.00	Gas Generation from Concrete	Excluded	Low Consequence	WP, WF Misc
79	2.1.12.06.00	Gas Transport in Waste and EBS	Excluded	Low Consequence	WF Misc
80	2.1.12.07.00	Radioactive Gases in Waste and EBS	Excluded	Low Consequence	
81	2.1.12.08.00	Gas Explosions	Excluded	Low Consequence	WF Misc
82	2.1.13.01.00	Radiolysis	Excluded	Low Consequence	WF Misc
83	2.1.13.02.00	Radiation Damage in Waste and EBS	Excluded	Low Consequence	WF Misc
84	2.1.13.03.00	Mutation	Excluded	Low Consequence	WP, WF Misc
85	2.2.01.04.00	Elemental Solubility in Excavation Disturbed Zone	Excluded	Low Consequence	
86	2.2.07.06.00	Episodic / Pulse Release from Repository	Included (flow into EBS) Excluded (pulse release)	Low Consequence	WP, WF Misc
87	2.2.08.04.00	Redissolution of Precipitates Directs More Corrosive Fluids to Containers	Included		WF Col WF Misc
88	2.2.11.02.00	Gas Pressure Effects	Excluded	Low Consequence	UZ

(*) This feature is not part of the current repository baseline design (CRWMS M&O 2000bb).
(1) Should backfill be included in the design, this decision may change from Excluded to Included.
(2) Should backfill be included in the design, this screening basis would change from Probability to Consequence.
(3) The exclusion of this FEP results in a conservative dose estimate.

Table 9. Summary of Screening Decisions for both Primary and Secondary EBS FEPs

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
1	1.1.02.00.00	Excavation/Construction	Excluded	Low Consequence	NFE, UZ
	1.1.02.00.01	Blasting and vibration	Excluded	Low Consequence	
	1.1.02.00.02	Geochemical alteration (excavation)	Excluded	Low Consequence	
	1.1.02.00.03	Groundwater chemistry (excavation)	Excluded	Low Consequence	
	1.1.02.00.04	Influx of oxidizing water	Excluded	Low Consequence	
	1.1.02.00.05	Influx of oxidizing water	Excluded	Low Consequence	
2	1.1.02.01.00	Site Flooding (During Construction and Operation)	Excluded	Low Consequence	UZ
	1.1.02.01.01	Repository flooding during operation	Excluded	Low Consequence	
3	1.1.02.02.00	Effects of Preclosure Ventilation	Included		NFE
	1.1.02.02.01	Gas generation, near-field rock	Excluded	Low Probability	
4	1.1.02.03.00	Undesirable Materials Left	Excluded	Low Consequence	
	1.1.02.03.01	Decontamination materials left	Excluded	Low Consequence	
	1.1.02.03.02	Inadvertent inclusion of undesirable materials	Excluded	Low Consequence	
5	1.1.03.01.00	Error in Waste or Backfill Emplacement	Excluded (high-consequence undetected errors) Excluded (other undetected errors)	Low Probability Low Consequence	WP
	1.1.03.01.01	Inadequate backfill or compaction, voidage	Excluded	Low Probability	
	1.1.03.01.02	Containers are improperly placed – on drift floor	Excluded (high-consequence undetected errors) Excluded (other undetected errors)	Low Probability Low Consequence	
	1.1.03.01.03	Containers are placed too close together	Excluded (high-consequence undetected errors) Excluded (other undetected errors)	Low Probability Low Consequence	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	1.1.03.01.04	Emplacement error – containers placed in wet zone	Excluded (high-consequence undetected errors) Excluded (other undetected errors)	Low Probability Low Consequence	
6	1.1.07.00.00	Repository Design	Included (other effects) Excluded (design deviations)	Low Consequence	SYS
	1.1.07.00.01	Poorly designed repository	Included (other effects) Excluded (design deviations)	Low Consequence	
	1.1.07.00.02	Design modification	Included (other effects) Excluded (design deviations)	Low Consequence	
	1.1.07.00.03	HLW panels (siting)	Excluded	Low Probability	
	1.1.07.00.04	TRU silos (siting)	Excluded	Low Probability	
	1.1.07.00.05	Access tunnels and shafts	Excluded	Low Probability	
	1.1.07.00.06	Design and Construction FEPs	Included (other effects) Excluded (design deviations)	Low Consequence	
	1.1.07.00.07	Design and Construction	Included (other effects) Excluded (design deviations)	Low Consequence	
	1.1.07.00.08	Design and Construction FEPs	Included (other effects) Excluded (design deviations)	Low Consequence	
7	1.1.08.00.00	Quality Control	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	SYS

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	1.1.08.00.01	Poorly constructed repository	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	
	1.1.08.00.02	Material defects	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	
	1.1.08.00.03	Common cause failures	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	
	1.1.08.00.04	Poor quality construction	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	
	1.1.08.00.05	Quality Control	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	
	1.1.08.00.06	Quality Control	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	
	1.1.08.00.07	Drains, installed to divert water around containers, are improperly placed	Included (specified defects and deviations) Excluded (other defects and deviations)	Low Consequence	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
8	1.1.12.01.00	Accidents and Unplanned Events During Operation	Excluded	Low Consequence	SYS
	1.1.12.01.01	Preclosure events	Excluded	Low Consequence	
	1.1.12.01.02	Sabotage and improper operation	Excluded	Low Consequence	
	1.1.12.01.03	Accidents during operation	Excluded	Low Consequence	
	1.1.12.01.04	Accidents during operation	Excluded	Low Consequence	
	1.1.12.01.05	Handling accidents	Excluded	Low Consequence	
	1.1.12.01.06	Oil or organic fluid spill	Excluded	Low Consequence	
9	1.1.13.00.00	Retrievability	Included		SYS
	1.1.13.00.01	Retrievability	Included		
10	1.2.04.03.00	Igneous Intrusion into Repository	Included		DE
	1.2.04.03.01	Sill provides a permeable flow path	Included		
	1.2.04.03.02	Sill provides a flow barrier	Included		
	1.2.04.03.03	Sill intrudes repository openings	Included		
	1.2.04.03.04	Volcanism	Included		
	1.2.04.03.05	Intruding dikes	Included		
11	2.1.03.01.00	Corrosion of Waste Containers	Included	(EBS provides boundary conditions)	WP
	2.1.03.01.01	Metallic corrosion	Included	(EBS provides boundary conditions)	
	2.1.03.01.02	Corrosion on wetting (of waste container)	Included	(EBS provides boundary conditions)	
	2.1.03.01.03	Oxic corrosion (of waste container)	Included	(EBS provides boundary conditions)	
	2.1.03.01.04	Anoxic corrosion (of waste container)	Excluded	Low Probability	
	2.1.03.01.05	Total corrosion rate (of waste container)	Included	(EBS provides boundary conditions)	
	2.1.03.01.06	Corrosion of copper canister	Excluded	Low Probability	
	2.1.03.01.07	Corrosion of steel vessel	Excluded	Low Probability	
	2.1.03.01.08	Container metal corrosion	Included	(EBS provides boundary conditions)	
	2.1.03.01.09	Corrosion (of waste container)	Included	(EBS provides boundary conditions)	
	2.1.03.01.10	Uniform corrosion (of waste container)	Included	(EBS provides boundary conditions)	
	2.1.03.01.11	Corrosive agents, Sulfides, oxygen, etc.	Included	(EBS provides boundary conditions)	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.03.01.12	Water turnover, copper canister	Excluded	Low Probability	
12	2.1.03.10.00	Container Healing	Excluded	Low Consequence (3)	WP
	2.1.03.10.01	Corrosion products (physical effects)	Excluded	Low Consequence (3)	
13	2.1.03.12.00	Container Failure (Long-term)	Included	(EBS provides boundary conditions)	WP
	2.1.03.12.01	Canister failure (reference)	Excluded	Low Probability	
	2.1.03.12.02	Long-term physical stability (in waste and EBS)	Included	(EBS provides boundary conditions)	
14	2.1.04.01.00	Preferential Pathways in the Backfill (*)	Excluded (1)	Low Probability	
	2.1.04.01.01	Interaction and diffusion between canisters (and buffer/backfill)	Excluded (1)	Low Probability	
	2.1.04.01.02	Flow through buffer/backfill	Excluded (1)	Low Probability	
	2.1.04.01.03	Flow through buffer/backfill	Excluded (1)	Low Probability	
15	2.1.04.02.00	Physical and Chemical Properties of Backfill (*)	Excluded (1)	Low Probability	
	2.1.04.02.01	Backfill characteristics	Excluded (1)	Low Probability	
	2.1.04.02.02	Inhomogeneities (properties and evolution in buffer/backfill)	Excluded (1)	Low Probability	
	2.1.04.02.03	Chemical alteration of buffer/backfill	Excluded (1)	Low Probability	
	2.1.04.02.04	Backfill physical composition	Excluded (1)	Low Probability	
	2.1.04.02.05	Backfill chemical composition	Excluded (1)	Low Probability	
	2.1.04.02.06	Chemical degradation of backfill	Excluded (1)	Low Probability	
	2.1.04.02.07	Backfill material deficiencies	Excluded (1)	Low Probability	
	2.1.04.02.08	Near-field buffer chemistry	Excluded (1)	Low Probability	
	2.1.04.02.09	Water chemistry, tunnel backfill	Excluded (1)	Low Probability	
	2.1.04.02.10	Backfill effects on Cu corrosion	Excluded (1)	Low Probability	
16	2.1.04.03.00	Erosion or Dissolution of Backfill (*)	Excluded	Low Probability (2)	
	2.1.04.03.01	Erosion of buffer/backfill	Excluded	Low Probability (2)	
17	2.1.04.04.00	Mechanical Effects of Backfill (*)	Excluded (1)	Low Probability	
	2.1.04.04.01	Mechanical Failure of buffer/backfill	Excluded (1)	Low Probability	
	2.1.04.04.02	Mechanical impact/failure, buffer/backfill	Excluded (1)	Low Probability	
18	2.1.04.05.00	Backfill Evolution (*)	Excluded (1)	Low Probability	
	2.1.04.05.01	Hydrothermal alteration (in buffer/backfill)	Excluded (1)	Low Probability	
	2.1.04.05.02	Small pieces of backfill undergo phase changes when heated and welded together	Excluded (1)	Low Probability	
	2.1.04.05.03	Thermal degradation of buffer/backfill	Excluded (1)	Low Probability	
19	2.1.04.06.00	Properties of Bentonite (*)	Excluded	Low Probability	
	2.1.04.06.01,	Bentonite swelling pressure	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.04.06.02,	Bentonite erosion	Excluded	Low Probability	
	2.1.04.06.03,	Bentonite plasticity	Excluded	Low Probability	
	2.1.04.06.04,	Bentonite porewater chemistry	Excluded	Low Probability	
	2.1.04.06.05,	Mineralogical alteration – short term (in buffer/backfill)	Excluded	Low Probability	
	2.1.04.06.06,	Mineralogical alteration – long term (in buffer/backfill)	Excluded	Low Probability	
	2.1.04.06.07,	Bentonite cementation	Excluded	Low Probability	
	2.1.04.06.08,	Quality control (in buffer/backfill)	Excluded	Low Probability	
	2.1.04.06.09,	Poor emplacement of buffer	Excluded	Low Probability	
	2.1.04.06.10,	Organics/contamination of bentonite	Excluded	Low Probability	
	2.1.04.06.11,	Coagulation of bentonite	Excluded	Low Probability	
	2.1.04.06.12,	Dilution of buffer/backfill	Excluded	Low Probability	
	2.1.04.06.13,	Sedimentation of bentonite	Excluded	Low Probability	
	2.1.04.06.14,	Swelling of tunnel backfill	Excluded	Low Probability	
	2.1.04.06.15,	Swelling pressure (in buffer/backfill)	Excluded	Low Probability	
	2.1.04.06.16,	Degradation of bentonite by chemical reactions	Excluded	Low Probability	
	2.1.04.06.17,	Colloid generation (in buffer/backfill)	Excluded	Low Probability	
	2.1.04.06.18,	Coagulation of bentonite	Excluded	Low Probability	
	2.1.04.06.19,	Sedimentation of bentonite	Excluded	Low Probability	
	2.1.04.06.20,	Swelling of bentonite into tunnels and cracks	Excluded	Low Probability	
	2.1.04.06.21,	Uneven swelling of bentonite	Excluded	Low Probability	
	2.1.04.06.22,	Thermal effects on the buffer material	Excluded	Low Probability	
	2.1.04.06.23,	Bentonite emplacement and composition	Excluded	Low Probability	
	2.1.04.06.24,	Thermal evolution (in buffer/backfill)	Excluded	Low Probability	
	2.1.04.06.25,	Bentonite saturation	Excluded	Low Probability	
	2.1.04.06.26,	Buffer impermeability	Excluded	Low Probability	
	2.1.04.06.27,	Bentonite swelling	Excluded	Low Probability	
	2.1.04.06.28,	Resaturation of bentonite buffer	Excluded	Low Probability	
	2.1.04.06.29,	Resaturation of tunnel backfill	Excluded	Low Probability	
	2.1.04.06.30,	Effects of bentonite on groundwater chemistry	Excluded	Low Probability	
	2.1.04.06.31,	Canister/bentonite interaction	Excluded	Low Probability	
	2.1.04.06.32,	Interaction with cement components	Excluded	Low Probability	
	2.1.04.06.33,	Water chemistry, bentonite buffer	Excluded	Low Probability	
	2.1.04.06.34,	Gas transport in bentonite	Excluded	Low Probability	
	2.1.04.06.35,	Effect of bentonite swelling on EDZ	Excluded	Low Probability	
20	2.1.04.07.00	Buffer Characteristics (*)	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.04.07.01	Buffer additives	Excluded	Low Probability	
	2.1.04.07.02	Buffer evolution	Excluded	Low Probability	
	2.1.04.07.03	Faulty buffer emplacement	Excluded	Low Probability	
	2.1.04.07.04	Saturation of sorption sites	Excluded	Low Probability	
	2.1.04.07.05	Perturbed buffer material chemistry	Excluded	Low Probability	
21	2.1.04.08.00	Diffusion in Backfill (*)	Excluded	Low Probability (2)	
22	2.1.04.09.00	Radionuclide Transport Through Backfill (*)	Excluded	Low Probability (2)	
	2.1.04.09.01	Transport and release of nuclides, bentonite buffer	Excluded	Low Probability (2)	
	2.1.04.09.02	Transport and release of nuclides, tunnel backfill	Excluded	Low Probability (2)	
23	2.1.06.01.00	Degradation of Cementitious Materials in Drift	Included (drift degradation), Excluded (impact on seepage chemistry)	Low Consequence	
	2.1.06.01.01	Physio-chemical degradation of concrete	Included (drift degradation), Excluded (impact on seepage chemistry)	Low Consequence	
	2.1.06.01.02	Seal chemical composition	Included (drift degradation), Excluded (impact on seepage chemistry)	Low Consequence	
	2.1.06.01.03	Microbial growth on concrete	Included (drift degradation), Excluded (impact on seepage chemistry)	Low Consequence	
24	2.1.06.02.00	Effects of Rock Reinforcement Materials	Included (drift degradation), Excluded (impact on seepage chemistry)	Low Consequence	
	2.1.06.02.01	Degradation of rock reinforcement and grout	Included (drift degradation), Excluded (impact on seepage chemistry)	Low Consequence	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
25	2.1.06.03.00	Degradation of the Liner (*)	Excluded	Low Probability	
26	2.1.06.04.00	Flow Through the Liner (*)	Excluded	Low Probability	
	2.1.06.04.01	Fracture flow through the liner	Excluded	Low Probability	
27	2.1.06.05.00	Degradation of Invert and Pedestal	Included (pedestal) Excluded (invert)	Low Consequence	
	2.1.06.05.01	Cementitious invert	Excluded	Low Probability	
28	2.1.06.06.00	Effects and Degradation of Drip Shield	Included		WP
	2.1.06.06.01	Oxygen embrittlement of Ti drip shield	Included		
29	2.1.06.07.00	Effects at Material Interfaces	Excluded	Low Consequence	WP
30	2.1.07.01.00	Rockfall (Large Block)	Excluded	Low Consequence	WP, DE WF Clad, WF Misc,
	2.1.07.01.01	Rockbursts in container holes	Excluded	Low Consequence	
	2.1.07.01.02	Cave ins	Excluded	Low Consequence	
	2.1.07.01.03	Cave in (in waste and EBS)	Excluded	Low Consequence	
	2.1.07.01.04	Roof falls	Excluded	Low Consequence	
31	2.1.07.02.00	Mechanical Degradation or Collapse of Drift	Excluded	Low Consequence	DE
	2.1.07.02.01	Stability (in waste and EBS)	Excluded	Low Consequence	
	2.1.07.02.02	Mechanical (events and processes in the waste and EBS)	Excluded	Low Consequence	
	2.1.07.02.03	Rockfall stops up fault	Excluded	Low Consequence	
	2.1.07.02.04	Rockfall (rubble) (in waste and EBS)	Excluded	Low Consequence	
	2.1.07.02.05	Mechanical failure of repository	Excluded	Low Consequence	
	2.1.07.02.06	Subsidence/collapse	Excluded	Low Consequence	
	2.1.07.02.07	Vault collapse	Excluded	Low Consequence	
	2.1.07.02.08	Creeping of Rock Mass	Excluded	Low Consequence	
32	2.1.07.03.00	Movement of Containers	Included (contact with invert) Excluded (drip shield separation)	Low Consequence	
	2.1.07.03.01	Movement of canister in buffer/backfill	Excluded	Low Probability	
	2.1.07.03.02	Canister or container movement	Included (contact with invert) Excluded (drip shield separation)	Low Consequence	
	2.1.07.03.03	Movement of canister in buffer/backfill	Excluded	Low Probability	
	2.1.07.03.04	Canister sinking	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
33	2.1.07.04.00	Hydrostatic Pressure on Container (*)	Excluded	Low Probability	
	2.1.07.04.01	Excessive hydrostatic pressures (in waste and EBS)	Excluded	Low Probability	
	2.1.07.04.02	Changed hydrostatic pressure on canister	Excluded	Low Probability	
34	2.1.07.05.00	Creeping of Metallic Materials in the EBS	Excluded	Low Consequence	WP
	2.1.07.05.01	Creeping of copper	Excluded	Low Probability	
	2.1.07.05.02	External stress (in waste and EBS)	Excluded	Low Consequence	
	2.1.07.05.03	Voids in the lead filling	Excluded	Low Probability	
	2.1.07.05.04	Loss of ductility (of waste container)	Excluded	Low Probability	
	2.1.07.05.05	Incomplete filling of containers	Excluded	Low Probability	
35	2.1.07.06.00	Floor Buckling	Excluded	Low Consequence	
	2.1.07.06.01	Basin formation (in waste and EBS)	Excluded	Low Consequence	
36	2.1.08.01.00	Increased Unsaturated Water Flux at the Repository	Included		NFE, UZ
	2.1.08.01.01	Waste container is thermally quenched by rapid influx of water	Included		
37	2.1.08.02.00	Enhanced Influx (Philip's Drip)	Included		NFE, UZ
38	2.1.08.04.00	Cold Traps	Excluded	Low Consequence	
	2.1.08.04.01	Condensation forms on back of drifts	Excluded	Low Consequence	
39	2.1.08.05.00	Flow Through Invert	Included		
	2.1.08.05.01	Fracture flow through the invert	Included		
	2.1.08.05.02	UZ flow through/around the collapsed invert	Included		
40	2.1.08.06.00	Wicking in Waste and EBS	Included		
41	2.1.08.07.00	Pathways for Unsaturated Flow and Transport in the Waste and EBS	Included		WF Misc
	2.1.08.07.01	Residual canister (crack/hole effects)	Included		
	2.1.08.07.02	Properties of failed canister	Included		
	2.1.08.07.03	Container-partial corrosion	Included		
	2.1.08.07.04	Hydraulic conductivity (in waste and EBS)	Excluded	Low Probability	
	2.1.08.07.05	Consolidation of waste	Excluded	Low Probability	
	2.1.08.07.06	Channeling within the waste	Included		
	2.1.08.07.07	Unsaturated transport (water transport)	Included		
	2.1.08.07.08	Radionuclide transport (water transport)	Included		
42	2.1.08.08.00	Induced Hydrological Changes in the Waste and EBS	Included		WF Misc
43	2.1.08.09.00	Saturated Groundwater Flow in Waste and EBS	Excluded	Low Consequence	
	2.1.08.09.01	Hydraulic head (in waste and EBS)	Excluded	Low Probability	
	2.1.08.09.02	Cavitation	Excluded	Low Probability	
44	2.1.08.11.00	Resaturation of Repository	Included		NFE

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.08.11.01	Reflooding (in waste and EBS)	Included		
	2.1.08.11.02	Brine inflow (in waste and EBS)	Included		
45	2.1.08.12.00	Drainage with Transport – Sealing and Plugging	Excluded	Low Consequence	
46	2.1.08.13.00	Drains (*)	Excluded	Low Probability	
47	2.1.08.14.00	Condensation on Underside of Drip Shield	Excluded	Low Consequence	
48	2.1.09.01.00	Properties of the Potential Carrier Plume in the Waste and EBS	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.01	Reactions with cement pore water	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.02	Reactions with cement pore water	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.03	Induced chemical changes (in waste and EBS)	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.04	Interactions of host materials and ground water with repository material	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.05	TRU silos cementitious plume	Excluded	Low Probability	
	2.1.09.01.06	Water chemistry, canister	Excluded	Low Probability	
	2.1.09.01.07	Transport of chemically-active substances into the near-field	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.08	Incomplete near-field chemical conditioning	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.09.01.09	Chemical processes (in waste and EBS)	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.10	Hyperalkaline carrier plume forms	Excluded	Low Probability	
	2.1.09.01.11	Chemical interactions (in waste and EBS)	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.12	TRU alkaline or organic plume	Excluded	Low Probability	
	2.1.09.01.13	Interactions of waste and repository materials with host materials	Included (other effects) Excluded (cementitious leachate and corrosion products)	Low Consequence	
	2.1.09.01.14	TRU alkaline or organic plume	Excluded	Low Probability	
49	2.1.09.02.00	Interaction with Corrosion Products	Included (colloids) Excluded (other effects)	Low Consequence	
	2.1.09.02.01	Interactions with corrosion products and waste	Included (colloids) Excluded (other effects)	Low Consequence	
	2.1.09.02.02	Effects of metal corrosion (in waste and EBS)	Included (colloids) Excluded (other effects)	Low Consequence	
	2.1.09.02.03	Container corrosion products	Included (colloids) Excluded (other effects)	Low Consequence	
	2.1.09.02.04	Chemical buffering (canister corrosion products)	Included (colloids) Excluded (other effects)	Low Consequence	
	2.1.09.02.05	Radionuclide sorption and co-precipitation (in EBS)	Excluded	Low Consequence (3)	
50	2.1.09.05.00	In-drift Sorption	Excluded	Low Consequence (3)	NFE, WF Misc
	2.1.09.05.01	Selective sorption of Pu from solution	Excluded	Low Consequence (3)	
	2.1.09.05.02	Sorption	Excluded	Low Consequence (3)	
	2.1.09.05.03	Radionuclide retardation	Excluded	Low Probability	
	2.1.09.05.04	Sorption on filling materials	Excluded	Low Consequence (3)	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
51	2.1.09.06.00	Reduction-oxidation Potential in Waste and EBS	Included		WF Misc
	2.1.09.06.01	Redox front (in waste and EBS)	Included		
	2.1.09.06.02	Reduction-oxidation fronts (in waste and EBS)	Included		
	2.1.09.06.03	Localized reducing zones (in waste and EBS)	Included		
	2.1.09.06.04	Redox front (in buffer/backfill)	Excluded	Low Probability	
	2.1.09.06.05	Fe control of oxidation state of contaminants	Included		
52	2.1.09.07.00	Reaction Kinetics in Waste and EBS	Excluded	Low Consequence	WF Misc
	2.1.09.07.01	Reaction kinetics (in waste and EBS)	Excluded	Low Consequence	
53	2.1.09.08.00	Chemical Gradients/Enhanced Diffusion in Waste and EBS	Included (diffusion out WP and through invert) Excluded (within WF)	Low Consequence	WF Misc
	2.1.09.08.01	Enhanced diffusion (in waste and EBS)	Included (diffusion out WP and through invert) Excluded (within WF)	Low Consequence	
	2.1.09.08.02	Chemical gradients (in waste and EBS)	Included (diffusion out WP and through invert) Excluded (within WF)	Low Consequence	
	2.1.09.08.03	Diffusion in and through failed canister	Included (diffusion out WP and through invert) Excluded (within WF)	Low Consequence	
54	2.1.09.11.00	Waste-Rock Contact	Excluded	Low Consequence	WF Misc
55	2.1.09.12.00	Rind (Altered Zone) Formation in Waste, EBS, and Adjacent Rock	Excluded	Low Consequence	WF Misc
	2.1.09.12.01	Deep alteration of the porosity of drift walls	Excluded	Low Consequence	
56	2.1.09.13.00	Complexation by Organics in Waste and EBS	Excluded	Low Consequence	WF Misc
	2.1.09.13.01	Methylation (in waste and EBS)	Excluded	Low Consequence	
	2.1.09.13.02	Humic and fulvic acids	Excluded	Low Consequence	
	2.1.09.13.03	Complexation by organics	Excluded	Low Consequence	
	2.1.09.13.04	Fulvic acid	Excluded	Low Consequence	
	2.1.09.13.05	Humic acid	Excluded	Low Consequence	
	2.1.09.13.06	Complexing agents	Excluded	Low Consequence	

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	2.1.09.13.07	Organics (complexing agents)	Excluded	Low Consequence	
	2.1.09.13.08	Organics (complexing agents)	Excluded	Low Consequence	
	2.1.09.13.09	Organic complexation	Excluded	Low Consequence	
	2.1.09.13.10	Organic ligands	Excluded	Low Consequence	
	2.1.09.13.11	Kinetics of organic complexation	Excluded	Low Consequence	
	2.1.09.13.12	Introduced complexing agents	Excluded	Low Consequence	
57	2.1.09.14.00	Colloid Formation in Waste and EBS	Included		NFE, WF Misc
	2.1.09.14.01	Colloid generation-source term (in waste and EBS)	Excluded	Low Probability	
	2.1.09.14.02	Agglomeration of Pu colloids	Included		
	2.1.09.14.03	Colloids (in waste and EBS)	Included		
	2.1.09.14.04	Colloids/particles in canister	Included		
	2.1.09.14.05	Colloid formation	Included		
	2.1.09.14.06	Colloids	Included		
	2.1.09.14.07	Colloids, complexing agents	Included		
	2.1.09.14.08	Colloid generation and transport	Included		
	2.1.09.14.09	Colloid formation, dissolution and transport	Included		
	2.1.09.14.10	Colloid generation and transport	Included		
	2.1.09.14.11	Colloid formation and stability	Included		
58	2.1.09.15.00	Formation of True Colloids in Waste and EBS	Excluded	Low Consequence	WF Misc
59	2.1.09.16.00	Formation of Pseudo-colloids (Natural) in Waste and EBS	Included		WF Col
	2.1.09.16.01	Pseudo colloids	Included		
	2.1.09.16.02	Pseudo colloids	Included		
	2.1.09.16.03	Natural colloids	Included		
	2.1.09.16.04	Natural colloids	Included		
60	2.1.09.17.00	Formation of Pseudo-colloids (Corrosion Products) in Waste and EBS	Included		WF Col
	2.1.09.17.01	Colloid formation is associated with container hydrolosis products	Included		
61	2.1.09.18.00	Microbial Colloid Transport in the Waste and EBS	Excluded	Low Consequence	WF Col
62	2.1.09.19.00	Colloid Transport and Sorption in the Waste and EBS	Included (transport) Excluded (sorption)	Low Consequence	WF Col
	2.1.09.19.01	Colloid transport	Included (transport) Excluded (sorption)	Low Consequence	
63	2.1.09.20.00	Colloid Filtration in the Waste and EBS	Excluded	Low Consequence	WF Col
	2.1.09.20.01	Colloid filtration by the invert	Excluded	Low Consequence	

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	2.1.09.20.02	Colloid filtration (in pores and fractures)	Excluded	Low Consequence	
	2.1.09.20.03	Colloid filtration	Excluded	Low Probability	
64	2.1.09.21.00	Suspensions of Particles Larger than Colloids	Excluded	Low Consequence	WF Col
	2.1.09.21.01	Suspended sediment transport	Excluded	Low Consequence	
	2.1.09.21.02	Rinse	Excluded	Low Consequence	
65	2.1.10.01.00	Biological Activity in Waste and EBS	Included (MIC) Excluded (other effects)	Low Consequence	WF Col
	2.1.10.01.01	Microbial activity accelerates corrosion of containers	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.02	Microbial activity accelerates corrosion of cladding	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.03	Microbial activity accelerates corrosion of contaminants	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.04	Microbes (in waste and EBS)	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.05	Microorganisms (in waste and EBS)	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.06	Microbial effects (in waste and EBS)	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.07	Microbial activity (in waste and EBS)	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.08	Microbial activity (in waste and EBS)	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.09	Microbial activity (in waste and EBS)	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.10	Microbial interactions	Included (MIC) Excluded (other effects)	Low Consequence	
	2.1.10.01.11	Biofilms	Included (MIC) Excluded (other effects)	Low Consequence	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
66	2.1.11.01.00	Heat Output / Temperature in Waste and EBS	Included (other effects) Excluded (exothermic reactions)	Low Consequence	SZ, WF Col
	2.1.11.01.01	Glass temperature (in waste and EBS)	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
	2.1.11.01.02	Canister temperature	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
	2.1.11.01.03	Temperature, bentonite buffer	Excluded	Low Probability	
	2.1.11.01.04	Temperature, canister	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
	2.1.11.01.05	Temperature, tunnel backfill	Excluded	Low Probability	
	2.1.11.01.06	Heat generation from waste containers	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
	2.1.11.01.07	Radioactive decay heat	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
	2.1.11.01.08	DOE SNF expected waste heat generation	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
	2.1.11.01.09	DOE SNF expected waste heat generation	Included (other effects) Excluded (exothermic reactions)	Low Consequence	
67	2.1.11.03.00	Exothermic Reactions in Waste and EBS	Excluded	Low Consequence	WP, WF Col
	2.1.11.03.01	Concrete hydration	Excluded	Low Consequence	
68	2.1.11.04.00	Temperature Effects / Coupled Processes in Waste and EBS	Included		NFE, WF Misc
	2.1.11.04.01	Thermal (processes)	Included		
	2.1.11.04.02	Temperature effects (unexpected effects) (in waste and EBS	Included		
	2.1.11.04.03	Heat from radioactive decay (in waste and EBS)	Included		
	2.1.11.04.04	Long-term transients (in waste and EBS)	Included		
	2.1.11.04.05	Time dependence (in waste and EBS)	Included		

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	2.1.11.04.06	Coupled processes (in waste and EBS)	Included		
69	2.1.11.05.00	Differing Thermal Expansion of Repository Components	Excluded	Low Consequence	WF Misc
	2.1.11.05.01	Differing thermal expansion of near-field barriers	Excluded	Low Probability	
	2.1.11.05.02	Shearing of waste containers by secondary stresses from thermal expansion of the rock	Excluded	Low Probability	
	2.1.11.05.03	Differential elastic response (in waste and EBS)	Excluded	Low Consequence	
	2.1.11.05.04	Non-elastic response (in waste and EBS)	Excluded	Low Consequence	
70	2.1.11.07.00	Thermally-induced Stress Changes in Waste and EBS	Included		WF Misc
	2.1.11.07.01	Changes in in-situ stress field (in waste and EBS)	Included		
	2.1.11.07.02	Stress field changes, settling, subsidence or caving	Included		
71	2.1.11.08.00	Thermal Effects: Chemical and Microbiological Changes in the Waste and EBS	Included		WP, WF Misc
72	2.1.11.09.00	Thermal Effects on Liquid or Two-phase Fluid Flow in the Waste and EBS	Included		WF Misc
	2.1.11.09.01	Convection effects on transport (Enhanced vapor diffusion)	Included		
	2.1.11.09.02	Multiphase flow and gas-driven transport (water transport)	Included		
73	2.1.11.10.00	Thermal Effects on Diffusion (Soret effect) in Waste and EBS	Excluded	Low Consequence	WF Misc
	2.1.11.10.01	Soret effect (in waste and EBS)	Excluded	Low Consequence	
	2.1.11.10.02	Thermal effects: Transport (diffusion) effects (in waste and EBS)	Excluded	Low Consequence	
	2.1.11.10.03	Soret effect (water transport)	Excluded	Low Consequence	
74	2.1.12.01.00	Gas Generation	Excluded	Low Consequence	WF Misc
	2.1.12.01.01	Formation of gases (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.01.02	Gas generation	Excluded	Low Consequence	
	2.1.12.01.03	Gas generation, buffer/backfill	Excluded	Low Probability	
	2.1.12.01.04	Chemotoxic gases (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.01.05	Pressurization (in waste and EBS)	Excluded	Low Probability	
75	2.1.12.02.00	Gas Generation (He) from Fuel Decay	Excluded	Low Consequence	WF Misc
	2.1.12.02.01	Helium gas production	Excluded	Low Consequence	
	2.1.12.02.02	Internal pressure (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.02.03	Gas generation, canister	Excluded	Low Consequence	
	2.1.12.02.04	Internal pressure (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.02.05	He gas production (in waste and EBS)	Excluded	Low Consequence	
76	2.1.12.03.00	Gas Generation (H_2) from Metal Corrosion	Excluded	Low Consequence	WF Misc
	2.1.12.03.01	Chemical effects of corrosion	Excluded	Low Consequence	
	2.1.12.03.02	Effect of hydrogen on corrosion	Excluded	Low Consequence	
	2.1.12.03.03	Hydrogen production (in waste and EBS)	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.12.03.04	Hydrogen production by metal corrosion	Excluded	Low Consequence	
	2.1.12.03.05	Container material inventory	Excluded	Low Consequence	
77	2.1.12.04.00	Gas Generation (CO_2, CH_4, H_2S) from Microbial Degradation	Excluded	Low Consequence	WF Misc
	2.1.12.04.01	Effect of temperature on microbial gas generation	Excluded	Low Consequence	
	2.1.12.04.02	Effect of pressure on microbial gas generation	Excluded	Low Consequence	
	2.1.12.04.03	Effect of radiation on microbial gas generation	Excluded	Low Consequence	
	2.1.12.04.04,	Effect of biofilms on microbial gas generation	Excluded	Low Consequence	
	2.1.12.04.05,	Methane and carbon dioxide by microbial degradation	Excluded	Low Consequence	
78	2.1.12.05.00	Gas Generation from Concrete	Excluded	Low Consequence	WP, WF Misc
79	2.1.12.06.00	Gas Transport in Waste and EBS	Excluded	Low Consequence	WF Misc
	2.1.12.06.01	Thermo-chemical effects (related to gas in waste and EBS)	Excluded	Low Consequence	
	2.1.12.06.02	Gas transport	Excluded	Low Consequence	
	2.1.12.06.03	Gas effects (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.06.04	Gas escape from canister	Excluded	Low Consequence	
	2.1.12.06.05	Gas flow and transport, buffer/backfill	Excluded	Low Probability	
	2.1.12.06.06	Gas transport	Excluded	Low Consequence	
	2.1.12.06.07	Unsaturated flow due to gas production (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.06.08	Gas permeability (in buffer/backfill)	Excluded	Low Probability	
80	2.1.12.07.00	Radioactive Gases in Waste and EBS	Excluded	Low Consequence	
	2.1.12.07.01	Radioactive gas (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.07.02	Gaseous and volatile isotopes	Excluded	Low Consequence	
81	2.1.12.08.00	Gas Explosions	Excluded	Low Consequence	WF Misc
	2.1.12.08.01	H_2/O_2 explosions (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.08.02	Flammability (in waste and EBS)	Excluded	Low Consequence	
	2.1.12.08.03	Explosions	Excluded	Low Consequence	
	2.1.12.08.04	Explosion	Excluded	Low Consequence	
82	2.1.13.01.00	Radiolysis	Excluded	Low Consequence	WF Misc
	2.1.13.01.01	Radiolysis (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.01.02	Radiolysis	Excluded	Low Consequence	
	2.1.13.01.03	Radiolysis (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.01.04	Radiolysis (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.01.05	Radiolysis prior to wetting (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.01.06	Radiolysis of brine	Excluded	Low Consequence	
	2.1.13.01.07	Radiolysis of cellulose (in waste and EBS)	Excluded	Low Probability	

#	YM FEP Database FEP #	YM FEP Database FEP Name	TSPA-EBS Screening Decision	TSPA-EBS Screening Basis	Other PMRs
	2.1.13.01.08	Radiolysis	Excluded	Low Consequence	
	2.1.13.01.09	Radiolysis	Excluded	Low Consequence	
83	2.1.13.02.00	Radiation Damage in Waste and EBS	Excluded	Low Consequence	WF Misc
	2.1.13.02.01	Radiation effects (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.02.02	Radiation effects on bentonite	Excluded	Low Probability	
	2.1.13.02.03	Material property changes (due to radiation in waste and EBS)	Excluded	Low Consequence	
	2.1.13.02.04	Radiation damage (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.02.05	Radiation shielding (in waste and EBS)	Excluded	Low Consequence	
	2.1.13.02.06	Radiation effects on buffer/backfill	Excluded	Low Probability	
	2.1.13.02.07	Radiation effects on canister	Excluded	Low Consequence	
	2.1.13.02.08	Radiological effects on waste	Excluded	Low Consequence	
	2.1.13.02.09	Radiological effects on containers	Excluded	Low Consequence	
	2.1.13.02.10	Radiological effects on seals	Excluded	Low Consequence	
	2.1.13.02.11	Radiological effects on canisters	Excluded	Low Probability	
84	2.1.13.03.00	Mutation	Excluded	Low Consequence	WP, WF Misc
85	2.2.01.04.00	Elemental Solubility in Excavation Disturbed Zone	Excluded	Low Consequence	
86	2.2.07.06.00	Episodic / Pulse Release from Repository	Included (flow into EBS) Excluded (pulse release)	Low Consequence	WP, WF Misc
87	2.2.08.04.00	Redissolution of Precipitates Directs More Corrosive Fluids to Containers	Included		WF Col WF Misc
88	2.2.11.02.00	Gas Pressure Effects	Excluded	Low Consequence	UZ
	2.2.11.02.01	Gas pressure effects	Excluded	Low Consequence	
	2.2.11.02.02	Fluid flow due to gas pressurization (in waste and EBS)	Excluded	Low Consequence	
	2.2.11.02.03	Disruption due to gas effects	Excluded	Low Probability	

(*) This feature is not part of the current repository baseline design (CRWMS M&O 2000bb).
(1) Should backfill be included in the design, this decision may change from Excluded to Included.
(2) Should backfill be included in the design, this screening basis would change from Probability to Consequence.
(3) The exclusion of this FEP results in a conservative dose estimate.
(4) While this FEP is excluded from the TSPA, any possible effects are conservatively bounded by other modeling assumptions.

ATTACHMENT I

PRELIMINARY EBS PROCESS MODEL FEP SCREENING CONSIDERATIONS

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ATTACHMENT I

PRELIMINARY EBS PROCESS MODEL FEP SCREENING CONSIDERATIONS

Table I-1 of this attachment includes preliminary process model considerations for inclusion/exclusion of selected Engineered Barrier System (EBS) Features, Events, and Processes (FEPs) in/from the Total System Performance Assessment (TSPA). Section 6.4 in the main body of this document addresses the screening of all EBS FEPs. The considerations are based on information provided in process model Analysis/Model Reports listed and referenced in Table 7, and used as input to the screening arguments in Section 6.4 of this AMR. Future modeling and analysis efforts may enhance these considerations, and in this sense they are preliminary. It is noted that the screening decisions in Section 6.4 are made from the TSPA point of view for EBS, and as such, may differ from these considerations, and decisions of other Process Model Reports for a given FEP.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
			INCLUSION	EXCLUSION
1.1.02.00.00	Excavation/ construction	This FEP is concerned with the effects associated with excavation/construction of the underground regions of the repository on the long-term behavior of the engineered and natural barriers. Excavation-related effects include changes to rock properties due to boring and blasting and chemical changes to the rock and incoming groundwater due to potential explosives residue. Excavation and other construction activities could also directly cause groundwater chemistry changes within the tunnel due to the impact of such contaminants as diesel exhaust, explosives residues, or other organic contaminants (Secondary FEP 1.1.02.00.03). Finally, oxidizing water introduced into the repository during excavation/construction could impact repository conditions/performance (Secondary FEP 1.1.02.00.04). [NFE, UZ]		Chemical effects of excavation are negligible; contamination will be limited through the use of tunnel boring (instead of drill-and-blast) and electrically powered equipment, which will limit microbial effects caused by excavation, as well as abiotic chemical contamination (CRWMS M&O 2000k, Sections 6.3 & 6.4). Sufficient drainage capacity in the drift floor will remain even after fines migration associated with excavation, based on observed drainage behavior in exploratory tunnels (CRWMS M&O 2000i, Section 6.2). Rockfall models are based on observation of rock characteristics in the as-built (post-excavation) condition, so that excavation effects, if any, are included. Other effects of excavation on rockmass response are minor (CRWMS M&O 2000h, Section 6). The ambient host rock is already oxidizing, as evidenced by the prevalence of iron in the form of ferric oxides, and the atmospheric fugacity of oxygen in the gas phase (CRWMS M&O 2000k, Section 6.2).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
1.1.02.02.00	Effects of pre-closure ventilation	The duration of preclosure ventilation acts together with waste package spacing (as per design) to control the extent of the boiling front within the NFE. [NFE]	Heat removal by ventilation is included in TH models for TSPA and evaluation of FEPs (CRWMS M&O 2000i, Section 6.3); (CRWMS M&O 2000m, Sections 4.1.13 and 5.3.1).	
1.1.13.00.00	Retriev-ability	This category contains FEPs related to design, emplacement, operational, or administrative measures that might be applied or considered in order to enable or ease retrieval of wastes. There may be a requirement to retrieve all or part of the waste stored in the repository (e.g., to recover valuable fissile materials or to replace defective containers.) [SYS]	Processes and design features which would facilitiate retrieval are included in process models (CRWMS M&O 2000b, Section 6.3; CRWMS M&O 2000l, Section 6.3; CRWMS M&O 2000m, Section 6.12).	

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.03.01.00	Corrosion of waste containers	Corrosion may contribute to waste package failure. Corrosion is most likely to occur at locations where water drips on the waste packages, but other mechanisms should be considered. [WP]	The quantity, distribution, and chemistry of water that could contact the waste packages is included in the EBS process models for TSPA and evaluation of FEPs. Chemical conditions are considered for conditions without seepage (CRWMS M&O 2000k, Section 6.7). Water diversion performance of the drip shield is described (CRWMS M&O 2000i, Section 6.1). See the UZ PMR for discussion of seepage quantity, and the WP PMR for discussion of corrosion modes and rates for the drip shield and waste package. The Multiscale TH Model, (CRWMS M&O 2000m), is used as input to the thermal seepage abstraction used in TSPA, (CRWMS M&O 2000n). The liquid flux in the fractures 5 meters above the drift crown is calculated as a representation of percolation flux that could produce seepage during the thermal period. After the thermal period the ambient drift seepage model applies directly (CRWMS M&O 2000hh).	
2.1.03.10.00	Container healing	Pits and holes in waste packages could be partially or fully plugged by chemical or physical reactions during or after their formation, affecting corrosion processes and water flow and radionuclide transport through the breached container. Passivation by corrosion products is a potential mechanism for container healing. [WP]		Possible effects from deposition of corrosion products or mineral precipitates in breaches that may form in the drip shield or waste package, are not considered in the (CRWMS M&O 2000i). No benefit to water diversion performance is anticipated, only the potential for healing of breaches.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.03.12.00	Container failure (long-term)	Waste packages and drip shields have a potential to fail over long periods of time by a variety of mechanisms, including general corrosion, stress corrosion cracking, pit corrosion, hydride cracking, microbially-mediated corrosion, internal corrosion, and mechanical impacts. [WP]	Long-term failure of the drip shield and waste package will affect water diversion performance, and this is included in models developed for TSPA and evaluation of FEPs (CRWMS M&O 2000i, Section 6.1; also CRWMS M&O 2000j).	
2.1.06.01.00	Degradation of cementitious materials in drift	Degradation of cementitious material used for any purposes in the disposal region may affect long-term performance through both chemical and physical processes. Degradation may occur by physical, chemical, and microbial processes. Note that this FEP also encompasses FEPs: ebs # 22 and 26 from EBS FEPs AMR Rev00, Table 3; also see FEPs 2.1.06.01.00, 2.1.06.02.00.		Leachate from rockbolt cement grout (rockbolts would be used in one part of the potential repository) could seep into the drifts. Such leachate would initially be alkaline, but would be readily neutralized by the effects of CO_2 in the environment (CRWMS M&O 2000k, Section 6.3.1). Products of neutralization include calcite, which could accumulate on the drip shield. The effects of such leachate on the bulk chemical environment can be excluded on low consequence. Calcite is a minor mineral constituent of the host rock; small amounts in the invert will have a negligible effect on water composition along radionuclide transport pathways.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.06.02.00	Effects of rock reinforce-ment materials	Degradation of rock bolts, wire mesh, and other materials used in ground control may affect the long-term performance of the repository. Note that this FEP also encompasses FEPs: ebs # 12, 21, 22, and 26 from EBS FEPs AMR Rev00, Table 3; also see FEPs 2.1.06.01.00, 2.1.06.02.00.	The effects of ferric oxide colloids on the transport of radionuclides released from breached waste packages, have been bounded (CRWMS M&O 2000k, Section 6.6). Other models that incorporate colloidal transport of radionuclides in TSPA are described in the WF PMR, the EBS Radionuclide Transport Abstraction AMR, and associated AMRs.	Steel used in ground support would corrode, producing ferric oxides, and consuming oxygen. The effects of ferric oxide on water composition are shown to be negligible (CRWMS M&O 2000k, Section 6.7). The consumption of gas-phase oxygen by corroding steel may decrease the oxygen fugacity, but the effect will be of limited duration and intensity (CRWMS M&O 2000k, Sections 6.2 and 6.3). Microbial effects on the rate of steel degradation are also considered (CRWMS M&O 2000k, Section 6.4). The effect of ferric corrosion products on water composition in the ex-container EBS will be negligible because chemical reactions there are predominantly non-redox. Calculations show that ferric iron is not likely to be reduced even with oxygen fugacity on the order of 10^{-10} atm (CRWMS M&O 2000k, Section 6.7).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.06.05.00	Degradation of invert and pedestal	Degradation of the materials used in the invert and the pedestal supporting the waste package may occur by physical, chemical, or microbial processes, and may affect the long-term performance of the repository. Note that this FEP also encompasses FEPs: ebs # 1, 5, 8, 9, and 11 from EBS FEP AMR Rev00, Table 3; also see FEPs 2.1.06.06.00, 2.1.06.07.00, 2.1.07.01.00, 2.1.07.02.00.		Corrosion products from invert steel, and the waste package pedestal, will have a minimal effect on water, because these corrosion products are insoluble. Corrosion of steel used in the invert would produce ferric oxides, and consume oxygen. The effects of iron-containing clays (as surrogates for ferric oxides) on water composition are shown to be negligible (CRWMS M&O 2000k, Section 6.7). Possible effects from corroding stainless steel, titanium, and Alloy-22 are also considered. Consumption of gas-phase oxygen by corroding steel may decrease the oxygen fugacity, but the effect will be of limited duration and intensity (CRWMS M&O 2000k, Sections 6.2 and 6.3). Microbial effects on the rate of steel degradation are also considered (CRWMS M&O 2000k, Section 6.4). Drip shield, pedestal and waste package lifetime are 10,000 years per the PDD (CRWMS M&O 2000bb); failure occurs relatively early, with the result that transport distance is zero from the waste package to the invert.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.06.06.00	Effects and degradation of drip shield	The drip shield will affect the amount of water reaching the waste package. Behavior of the drip shield in response to rockfall, ground motion, and physical, chemical degradation processes should be considered. Effects of the drip shield on the disposal region environment (for example, changes in relative humidity and temperature below the shield) should be considered for both intact and degraded conditions. Degradation processes specific to the chosen material should be identified and considered. For example, oxygen embrittlement should be considered for titanium drip shields. Note that this FEP also encompasses FEPs ebs # 2, 9, 10, 11, 15, 17, 19, 20, 24, 30, 31, and 32 from table 3 [EBS FEP AMR Rev00, see FEPs 2.1.06.05.00, 2.1.06.07.00, 2.1.07.01.00, 2.1.07.02.00]. [WP].	Water diversion performance of the degraded drip shield is considered (CRWMS M&O 2000i, Section 6.1; also see CRWMS M&O 2000j).	Drip shield corrosion will occur slowly, and degradation potentially significant to environmental conditions will not occur until late during cooldown, or after cooldown (CRWMS M&O 2000v). Thus the temperature and relative humidity on the waste package would not differ much from elsewhere in the drift, or from the intact drip shield calculation results (CRWMS M&O 2000i, Section 6.3). The environment under the drip shield is evaluated for intact conditions which are argued to bound the potential for condensation under breached drip shields (CWRMS M&O 2000i, Section 6.4). Calculated drip shield temperature, and invert temperature and relative humidity, from the Multiscale TH Model have been manipulated to evaluate the potential for condensation. Condensate would be dilute, so the effect on corrosion rates for the waste package and drip shield would be negligible. See the WP PMR and associated abstraction AMRs for discussion of corrosion modes and rates.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.06.07.00	Effects at material interfaces	Physical and chemical effects that occur at the interfaces between materials in the drift, such as at the contact between the backfill and the drip shield, may affect the performance of the system. Note that this FEP also encompasses FEPs: ebs # 9 and 11 from EBS FEP AMR Rev00, Table 3; also see FEPs 2.1.06.05.00, 2.1.06.06.00, 2.1.07.01.00, and 2.1.07.02.00. [WP]	The chemical processes that occur at phase boundaries (e.g. between solid and liquid phases) are included in models for water composition and degradation of EBS materials (CRWMS M&O 2000k, Sections 6.3, 6.4, and 6.7). Heterogeneous electrochemical reactions are not considered explicitly, but the effects on the bulk chemical environment would be similar to the reactions considered. See the WP PMR and supporting documentation for evaluation of the effects of contact between corroded steel and the titantium drip shield.	
2.1.07.01.00	Rockfall (large block) WFClad—Rockfall	Rockfalls may occur that are large enough to mechanically tear or rupture waste packages. Note that this FEP also encompasses FEPs: ebs # 6, 9, and 11 from EBS FEP AMR Rev00, Table 3; also see FEPs 2.1.06.05.00, 2.1.06.06.00, 2.1.06.07.00, and 2.1.07.02.00. [WP, WF Clad, WF Misc, DE]		Rockfall models are based on extensive site characterization data. Probabilistic descriptions of rock size and rockfall frequency are provided for use in (CRWMS M&O 2000h) engineering design analyses applied to the drip shield, and underlying waste package (CRWMS M&O 2000ff, Section 6.8).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.07.02.00	Mechanical degradation or collapse of drift	Partial or complete collapse of the drifts, as opposed to discrete rockfall, could occur as a result of seismic activity, thermal effects, stresses related to excavation, or possibly other mechanisms. Drift collapse could affect stability of the engineered barriers and waste packages. Drift collapse may be localized as stopping at faults or other geologic features. Rockfall of small blocks may produce rubble throughout part or all of the tunnel. Note that this FEP also encompasses FEPs: ebs # 9, 11, and 37 from EBS FEP AMR Rev00, Table 3; also see FEPs 2.1.06.05.00, 2.1.06.06.00, 2.1.06.07.00, and 2.1.07.01.00. [DE]		Rockfall models are based on extensive site characterization data, and extend to conditions that can represent drift collapse. Probabilistic descriptions of rock size and rockfall frequency are provided for use in (CRWMS M&O 2000h) engineering design analyses applied to the drip shield, and underlying waste package (CRWMS M&O 2000ff, Section 6.8). Standoff criteria will be used to limit or prevent waste emplacement in the immediate vicinity of faults (CRWMS M&O 2000z, Section 1.2.2.1.4).
2.1.07.03.00	Movement of containers	Waste packages may move as a result of seismic activity, degradation of the invert or pedestal, rockfall, fault displacement, or other processes (also see FEP 2.1.06.05.00). Note that this FEP also encompasses FEP: ebs # 3 from EBS FEP AMR Rev00, Table 3; also see FEP 2.1.07.03.00.	Included by assumptions made for radionuclide transport from the waste package to the top of the invert (CRWMS M&O 2000j).	Rockfall models are based on site characterization data, and extend to conditions that can represent drift collapse. Probabilistic descriptions of rock size and rockfall frequency are provided for use in (CRWMS M&O 2000h) engineering design analyses applied to the drip shield, and underlying waste package (CRWMS M&O 2000ff, Section 6.8).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.07.04.00	Hydrostatic pressure on container	Waste packages emplaced in the saturated zone will be subjected to hydrostatic pressure in addition to stresses associated with the evolution of the waste and barrier system. This FEP is not relevant for the YMP design, which calls for emplacement in the		Free drainage conditions will prevail in the potential repository (CRWMS M&O 2000i, Section 6.2).
2.1.08.01.00	Increased unsaturated water flux at the repository	An increase in the unsaturated water flux at the repository affects thermal, hydrological, chemical, and mechanical behavior of the system. Extremely rapid influx could reduce temperatures below the boiling point during part or all of the thermal period. Increases in flux could result from climate change, but the cause of the increase is not an essential part of the FEP. [NFE, UZ]	Increased flux representing the uncertainty as to future climate change, is considered in thermal-hydrologic models (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m , Section 6.12).	Increased flux is considered in models o drainage (CRWMS M&O 2000i, Section 6.2), which showed that free drainage is expected to prevail in the potential repository for the range of flux considered.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.08.02.00	Enhanced influx (Philip's drip)	An opening in unsaturated rock alters the hydraulic potential, affecting local saturation around the opening and redirecting flow. Some of the flow is directed to the opening where it is available to seep into the opening. [NFE, UZ]	See the UZ PMR for discussion of drift seepage models. The possible presence of seepage is included in models for the chemical environment (CRWMS M&O 2000c), and water diversion performance of the drip shield and waste package (CRWMS M&O 2000i, Section 6.1). In addition, the effects of seepage on the temperature and relative humidity during the thermal period have been evaluated parametrically, and found to be minor (CRWMS M&O 2000i, Section 6.3). The Multiscale TH Model, (CRWMS M&O 2000m), is used as input to the thermal seepage abstraction used in TSPA (CRWMS M&O 2000n). The liquid flux in the fractures 5 meters above the drift crown is calculated as a representation of percolation flux that could produce seepage during the thermal period. After the thermal period the ambient drift seepage model applies directly (CRWMS M&O 2000hh).	
2.1.08.04.00	Cold Traps	Emplacement of waste in drifts creates a large thermal gradient across the drifts. Moisture condenses on the roof and flows downward through the backfill.	The effects of condensation on the chemical environment at the surface of the drip shield, is included in current models (CRWMS M&O 2000k, Section 6.7).	By analogy to the effects of seepage during the thermal period, such condensation would be inconsequential to the performance of the intact drip shield and/or drip shield (CRWMS M&O 2000i, Section 6.1).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.08.05.00	Flow through invert	The invert, consisting mostly of porous, crushed tuff, separates the waste package from the bottom of the tunnel (boundary to the UZ). Water may flow through the invert, either in its intact or degraded state, either in fractures or matrix porosity.	Unsaturated flow in the invert is included in thermal-hydrologic models, and the effects of seepage on this flow are evaluated (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m, Section 6.12).	
2.1.08.06.00	Wicking in waste and EBS	Capillary rise, or wicking, is a potential mechanism for water to move through the waste and engineered barrier system.	Unsaturated capillary flow is included in thermal-hydrologic models for TSPA and evaluation of FEPs (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m), and in models for drainage (CRWMS M&O 2000i, Section 6.2). Capillary processes are also included in models for water diversion performance of the drip shield and waste package (CRWMS M&O 2000i, Section 6.3).	
2.1.08.07.00	Pathways for unsaturated flow and transport in the waste and EBS	Unsaturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways. [WFMisc]	EBS radionuclide transport models that support TSPA are developed using a lumped-parameter approach that accommodates preferential pathways in the invert (CRWMS M&O 2000f, CRWMS M&O 2000j). Breaches in the drip shield and waste package are also treated as preferential pathways, in an average sense that holds for many waste packages (CRWMS M&O 2000i, Section 6.1).	The potential for evaporation in the invert to result in porosity changes that could change hydrologic properties, has been evaluated and found to be small (CRWMS M&O 2000k, Section 6.3.3).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.08.08.00	Induced hydrological changes in the waste and EBS	Thermal, chemical, and mechanical processes related to the construction of the repository and the emplacement of waste may induce changes in the hydrological behavior of the system. Note that this FEP also encompasses FEPs: ebs # 13 and 14 from EBS FEP AMR Rev00, Table 3; also see FEPs 2.1.08.08.00. [WFMisc]		Coupled processes of the type described here are only likely to decrease, rather than increase the transmissivity of breaches in the drip shield or waste package, and are not considered in these models (CRWMS M&O 2000i, Section 6.1), and thus, no credit is taken for potentially favorable conditions. See the WP PMR for discussion of material degradation modes for the drip shield and waste package. The effects of minerals and salts that may be deposited by evaporation in the invert are limited (CRWMS M&O 2000k, Section 6.3). See the NFE PMR for discussion of potential THC effects in the host rock adjacent to the drift openings.
2.1.08.09.00	Saturated groundwater flow in waste and EBS	Saturated flow and radionuclide transport may occur along preferential pathways in the waste and EBS. Physical and chemical properties of the EBS and waste form, in both intact and degraded states, should be considered in evaluating pathways.		The EBS outside the waste package will remain unsaturated because free drainage conditions will be maintained (CRWMS M&O 2000i, Section 6.2).
2.1.08.11.00	Resaturation of repository	Water content in the repository will increase following the peak thermal period. [NFE]	Return of moisture to the EBS environment is included in thermal-hydrologic models (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m, Section 6.12).	
2.1.08.12.00	Drainage with transport – sealing and plugging	Normal functioning of drainage in the drifts is not established, so how drainage will change if fractures are plugged is unclear. Suggestions include ponding until fractures in the wall are reached by the water level or until there is sufficient head to clear the fractures.		Analysis indicates that drainage capacity will be sufficient to handle extreme seepage into the drifts (CRWMS M&O 2000i, Section 6.2).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.09.01.00	Properties of the potential carrier plume in the waste and EBS	When unsaturated flow in the drifts is re-established following the peak thermal period, water will have chemical and physical characteristics influenced by the near field host rock and EBS. Water chemistry may be strongly affected by interactions with cementitious materials. [NFE, WFMisc]	Water composition in the EBS (before transport into the host rock) is calculated using seepage water composition as input.	The effects from introduced materials such as rockbolt grout and ferric oxide on water composition will be minor (CRWMS M&O 2000k, Sections 6.3 and 6.7).
2.1.09.02.00	Interaction with corrosion products	Corrosion products produced during degradation of the metallic portions of the EBS and waste package may affect the mobility of radionuclides. Sorption/desorption and coprecipitation/ dissolution processes may occur. Note that this FEP also encompasses FEP: ebs # 7 from EBS FEP AMR Rev00, Table 3; also see FEP 2.1.09.02.00. [WFMisc]		The effects of ferric oxides from steel corrosion on water composition are minor (CRWMS M&O 2000k, Section 6.7). Oxide corrosion products from the drip shield and waste package corrosion resistant materials are also considered to be negligible for the ex-container EBS bulk environment. Transport of radionuclides on colloids derived from corrosion products, is bounded (CRWMS M&O 2000k, Section 6.6).
2.1.09.05.00	In-drift sorption; WF and in-package sorption.	Sorption of radionuclides within the waste and EBS may affect the aqueous concentrations of radionuclides released to the EBS. [WFMisc]		Sorption of radionuclides onto corrosion produces in the EBS is excluded from models for TSPA (CRWMS M&O 2000j), and thus credit is not taken for potentially favorable conditions.
2.1.09.06.00	Reduction-oxidation potential in waste and EBS	The redox potential in the waste and EBS influences the oxidation of barrier and waste-form materials and the solubility of radionuclide species. Local variations in the redox potential can occur. [WFMisc]	Models for water composition in the EBS include constraints on redox potential, represented by the oxygen fugacity (CRWMS M&O 2000k, Section 6.7).	Potential effects from oxygen fugacity that is decreased by several orders of magniitude, on water composition in the emplacement drifts, are evaluated and found to be minor (CRWMS M&O 2000k, Section 6.7).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.09.07.00	Reaction kinetics in waste and EBS	Chemical reactions, such as radionuclide dissolution/ precipitation reactions and reactions controlling the reduction-oxidation state, may not be in equilibrium in the drift and waste environment. [WFMisc]		Seepage waters in the Ex-Container EBS will have already interacted extensively with the host rock, so that further interactions with crushed tuff in the invert will be limited. The effects of evaporative concentration involve precipitation of minerals and salts, and the water composition could differ if these precipitates were hindered. The effects of such kinetics will be limited, either because the waters can become highly concentrated in species of importance without exceeding solubility constraints, or the volume of such concentrated waters will be very small, or solubility constraints are exceeded and precipitation occurs (CRWMS M&O 2000k, Section 6.7).
2.1.09.08.00	Chemical gradients/ enhanced diffusion in waste and EBS	The existence of chemical gradients within the disposal system, induced naturally or resulting from repository material and waste emplacement, may influence the transport of contaminants of dissolved and colloidal species. This could include, for example, diffusion in and through failed canisters. [WFMisc]	Diffusive transport of radiounclides in the EBS is included in TSPA (CRWMS M&O 2000f, CRWMS M&O 2000j).	The possible effects of chemical heterogeneity on the bulk chemical environment are limited by the simplicity of the EBS system and the chemical non-reactivity of engineered materials (i.e. ferric oxides, other metal oxides). This is especially true after the steel ground support is corroded completely. Such effects are excluded from TSPA based on low consequence (CRWMS M&O 2000k, Section 6.7).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.09.11.00	Waste-rock contact	Waste and rock are placed in contact by mechanical failure of the drip shields and waste packages. Reactions between uranium, rock minerals, and water, in contact with both, precipitate uranium, leading spent fuel to dissolve more rapidly than if constrained by the equilibrium solubility of uranium. [WFMisc]	Considering chemical conditioning of waters that contact waste: waters present in the EBS will have already interacted extensively with the host rock (CRWMS M&O 2000k, Section 6.7). Thus, the mode of interaction that is caused by transport of aquous species is already included.	
2.1.09.12.00	Rind (altered zone) formation in waste, EBS, and adjacent rock	Thermo-chemical processes involving precipitation, condensation, and redissolution alter the properties of the waste, EBS, and the adjacent rock. These alterations may form a rind, or altered zone, in the rock, with hydrological, thermal, and mineralogical properties different from the current conditions. [NFE, WFMisc]		The potential for changes in properties of the crushed tuff invert, caused by local evaporation, is probably limited , especially directly under the waste packages (CRWMS M&O 2000k, Section 6.3).
2.1.09.13.00	Complex-ation by organics in waste and EBS	The presence of organic complexants in water in the waste and EBS could augment radionuclide transport by providing a transport mechanism in addition to simple diffusion and advection of dissolved material. Organic complexants may include materials found in natural groundwater such as humates and fulvates, or materials introduced with the waste or engineered materials. [WFMisc]		Organic complexants could be important for radionuclides which have limited solubility, however, in current models the transport of such radionuclides in the EBS is dominated by colloids, especially waste form colloids, and to a lesser extent ferric oxide colloids derived from steel (CRWMS M&O 2000k, Section 6.6). Also, the abundance of organics is probably far less than the abundance of inorganic vectors of transport.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.09.14.00	Colloid formation in waste and EBS	Colloids in the waste and EBS may affect radionuclide transport. Different types of colloids may exist initially or may form during the evolution of the system by a variety of mechanisms. This FEP aggregates all types of colloids into a single category. Technical discussions of colloids for the Yucca Mountain repository are presented separately for true colloids (FEP 2.1.09.15.00), natural pseudo-colloids (FEP 2.1.09.16.00), pseudo-colloids formed from corrosion products (FEP 2.1.09.17.00), and microbial colloids (FEP 2.1.09.18.00) [WFCol]	Colloidal transport for key radionuclides is included in TSPA (CRWMS M&O 2000e, Section 6).	The effects of ferric oxide colloids on the transport of radionuclides released from breached waste packages, have been bounded (CRWMS M&O 2000k, Section 6.6).
2.1.09.15.00	Formation of true colloids in waste and EBS	True colloids are colloidal-size assemblages (between approximately one nanometer and 1 micrometer in diameter) of radionuclide-containing compounds. They may form in the waste and EBS during waste-form degradation and radionuclide transport. True colloids are also called radionuclide intrinsic colloids (or actinide intrinsic colloids, for those including actinide elements.) [WFCol]	True colloids are included in the assessment of radionuclide release. See the WF PMR for discussion.	Formation and stability of true colloids in the EBS (outside the waste package) will tend to decrease rather than increase, given the presence of ferric oxide colloids and the possibility for dilution, both of which will tend to decrease the dissolved concentrations for radionuclides (CRWMS M&O 2000k, Section 6.6).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.09.16.00	Formation of pseudo-colloids (natural) in waste and EBS	Pseudo-colloids are colloidal-sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids include microbial colloids, mineral fragments, and humic and fulvic acids. This FEP addresses radionuclide-bearing colloids formed from host-rock materials and all interactions of the waste and EBS with the host rock environment except corrosion. Pseudo-colloids formed from corrosion of the waste form and EBS are discussed in FEP 2.1.09.17.00. Microbial colloids are discussed in FEP 2.1.09.18.00. [WFCol]	Colloids derived from natural material will be transported from the host rock, in seepage. Colloid concentrations observed in water samples obtained for site characterization, provide analogous information on the concentration and composition of natural colloids. See the WF PMR for discussion.	
2.1.09.17.00	Formation of pseudo-colloids (corrosion products) in waste and EBS	Pseudo-colloids are colloidal sized assemblages (between approximately 1 nanometer and 1 micrometer in diameter) of nonradioactive material that has radionuclides bound to it. Pseudo-colloids derived from corrosion products include microbial colloids, mineral fragments, and iron-oxide particles. [WFCol]	Ferric oxide colloids will be produced from corrosion of steel in the EBS including within the waste package. The potential contribution to radionuclide transport is included in TSPA. See the WF PMR for discussion.	Transport of radionuclides on pseudo-colloids derived from corrosion products, is bounded (CRWMS M&O 2000k, Section 6.6). Radionuclide sorption to ferric pseudo-colloids will be limited because irreversible waste form colloids will dominate transport of key radionuclides.
2.1.09.19.00	Colloid transport and sorption in the waste and EBS.	Interactions between radionuclide-bearing colloids and the waste and EBS may result in retardation of the colloids during transport by sorption mechanisms. [WFCol]		It is conservatively assumed for TSPA that there is no retardation of colloidal transport (CRWMS M&O 2000j).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.09.20.00	Colloid filtration in the waste and EBS.	Filtration processes may affect transport of radionuclide-bearing colloids in the waste and EBS. [WFCol]		It is conservatively assumed for TSPA that there is no filtration of colloidal transport (CRWMS M&O 2000j).
2.1.09.21.00	Suspensions of particles larger than colloids	Groundwater flow through the waste could remove radionuclide-bearing particles by a rinse mechanism. Particles of radionuclide bearing material larger than colloids could then be transported in water flowing through the waste and EBS by suspension. [SZ, WFCol]		Particles larger than colloids will have limited concentration, and transport will be limited. This is suggested for the EBS by the decreasing abundance of particles with increasing size, in natural waters. See the WF PMR for discussion of release modes.
2.1.10.01.00	Biological activity in waste and EBS	Biological activity in the waste and EBS may affect disposal-system performance by altering degradation processes such as corrosion of the waste packages and waste form (including cladding), by affecting radionuclide transport through the formation of colloids and biofilms, and by generating gases. [WP, WFCol]		Microbially mediated degradation of steel and other materials is included in the Microbial Communities Model that supports TSPA, however, biocolloidal transport is not included because the carrier particles are likely to be scarce compared to the availability of abiotic in organic modes of transport. e.g. compare biomass calculations (In-Drift Microbial Communities Model) with potential abundance of ferric oxide colloids (CRWMS M&O 2000k). Also, much of the radionuclide inventory that is sensitive to colloidal transport is already colloidal on release from the WP. Microbially mediated rates of steel corrosion are included in the screening argument used to exclude the effects of steel corrosion on oxygen fugacity (CRWMS M&O 2000b, Sections 6.2 and 6.3).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.11.01.00	Heat output/ temperature in waste and EBS	Temperature in the waste and EBS will vary through time. Heat from radioactive decay will be the primary cause of temperature change, but other factors to be considered in determining the temperature history include the in-situ geothermal gradient, thermal properties of the rock, EBS, and waste materials, hydrological effects, and the possibility of exothermic reactions (see FEP 2.1.11.03.00). Considerations of the heat generated by radioactive decay should take different properties of different waste types, including DSNF, into account. [NFE, WFMisc]	Heat and mass transfer processes are included in thermal-hydrologic models for TSPA and evaluation of FEPs (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m, Section 6.12).	
2.1.11.03.00	Exothermic Reactions and Other Thermal Effects in Waste Form and EBS	Exothermic reactions liberate heat and will alter the temperature of the disposal system and affect the properties of the repository and surrounding materials. Hydration of concrete used in the underground environment is an example of a possible exothermic reaction. [WFMisc]		The amount of cementitious material used in construction of the potential repository will be limited. The free energy released by corrosion of steel will likely be small compared to the heat produced by the spent fuel waste. Using the oxidation expression (CRWMS M&O 2000k), Equation 6.3-11 and free energy of hematite (CRWMS M&O 2000ii), the exothermic heat production is at least one order of magnitude less than the waste-generated in 10 years, at 1000 grams after closure.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.11.04.00	Temperature effects/ coupled processes in waste and EBS	This FEP broadly encompasses all coupled-process effects of temperature changes within the waste and EBS. Technical discussions relevant to this FEP are provided individually for each relevant process. See FEP 2.1.11.01.00 for a discussion of the temperature history of repository. See FEP 2.1.11.03.00 for a discussion of possible exothermic reactions. See FEP 2.1.11.05.00 for a discussion of the effects of differential thermal expansion of repository components. See FEP 2.1.11.07.00 for a discussion of thermally-induced stresses in the waste and EBS. See FEP 2.1.11.08.00 for a discussion of thermal effects on chemical and microbial processes. See FEP 2.1.11.09.00 for a discussion of thermal effects on fluid flow in the waste and EBS. See 2.1.11.10.00 for a discussion of the Soret effect. [WFMisc]	Effects of temperature changes on the EBS are addressed in the models that support TSPA or are used to evaluate FEPs (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000k, Sections 6.2, 6.3, 6.4, and 6.7; CRWMS M&O 2000m, Section 6.12).	
2.1.11.05.00	Differing thermal expansion of repository components	Thermally-induced stresses could alter the performance of the waste or EBS. For example, thermal stresses could create pathways for preferential fluid flow in the backfill or through the drip shield. [WP, WFMisc]		The EBS components are designed to accommodate thermal strains. Design criteria indicate that the drip shield will maintain water diversion performance for 10,000 yr, including through the thermal period (CRWMS M&O 2000jj, Section 1).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.11.07.00	Thermally-induced stress changes in waste and EBS	Thermally-induced stress changes in the waste and EBS may affect performance of the repository. Relevant processes include rockfall, drift stability, changes in physical properties of the disturbed rock zone around the repository, and changes in the physical properties of the surrounding rock. [WFMisc]		This report addresses relevant information for rockfall, ground support, and performance of the drip shield. Probabilistic descriptions of rock size and rockfall frequency, for conditions representing elevated stress and temperature, are provided for use in engineering design analyses (CRWMS M&O 2000h). No credit is taken for ground support (which could be impacted by thermal stress especially in the post-closure period) in rockfall models. The drip shield will be designed to perform over a range of temperatures that will occur over time in the potential repository.
2.1.11.08.00	Thermal effects: chemical and microbio-logical changes in the waste and EBS	Temperature changes may affect chemical and microbial processes in the waste and EBS. See FEP 2.1.10d for a discussion of microbial effects and subentries under 2.1.09 for a discussion of chemical effects. [WFMisc]	The effects of temperature changes are included in models of microbial activity (CRWMS M&O 2000b, Section 6.4) and in models of water composition (CRWMS M&O 2000k, Section 6.7) .	
2.1.11.09.00	Thermal effects on liquid or two-phase fluid flow in the waste and EBS	Temperature differentials may result in convective flow in the waste and EBS. [WFMisc]	Two-phase flow is included in thermal-hydrologic models (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m, Section 6.12) such that the indirect effects of such flow on other processes are also included (CRWMS M&O 2000k, Sections 6.2 and 6.7).	

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.11.10.00	Thermal effects on diffusion (Soret effect) in waste and EBS	The Soret effect is a diffusion process caused by a thermal gradient. In liquids having both light and heavy molecules (or ions), the heavier molecules tend to concentrate in the cold region. Temperature differences in the waste and EBS may result in a component of diffusive solute flux that is proportional to the temperature gradient. [WFMisc]		Temperature-driven solute diffusion will be dominated by advective and Fickian modes of transport. The Soret effect is important in materials such as clays for which advective transport is inhibited by low permeability (Hardin and Chesnut 1997).
2.1.12.01.00	Gas generation	Gas may be generated in the repository by a variety of mechanisms. Gas generation might lead to pressurization of the repository, produce multiphase flow, and affect radionuclide transport. This FEP aggregates all types of gas generation into a single category. Technical discussions are presented separately for gas generation from fuel decay (FEP 2.1.12.02.00), corrosion (FEP 2.1.12.03.00), microbial degradation (FEP 2.1.12.04.00), concrete (FEP 2.1.12.02.05.00), radioactive gases within the waste (FEP 2.1.12.07.00), and radiolysis (2.1.13.01.00). [UZ, WFMisc]	Two-phase flow processes are included in models for TSPA and evaluation of FEPs (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m , Section 6.12).	Gas generation will be dominated by evolution of water vapor. Nevertheless, the high-permeability host rock will not permit significant increase in total gas-phase pressure (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m, Section 6.12). It is likely that the rate of water vapor production during the thermal period will exceed production rates for gases that could ever be produced from the waste, or microbial activity, or radiolysis (CRWMS M&O 2000k, Section 6.2).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.12.03.00	Gas generation (H2) from metal corrosion	Gas generation can affect the mechanical behavior of the host rock and engineered barriers, chemical conditions, and brine flow, and, as a result, the transport of radionuclides. Gas generation due to oxic corrosion of waste containers, cladding, and/or structural materials will occur at early times following closure of the repository. Anoxic corrosion may follow the oxic phase, if all oxygen is depleted. The formation of a gas phase around the canister may even exclude water from the iron, thus inhibiting further corrosion. [WP, WFMisc]		Hydrogen could be produced from steel corrosion in the EBS, however, the high rate of gas-phase dilution will limit the concentration. TH calculations show that the gas phase will be well mixed throughout the emplacement drift openings. The environment will probably remain oxidizing (CRWMS M&O 2000k, Section 6.2).
2.1.12.04.00	Gas generation (CO2, CH4, H2S) from microbial degradation	Microbial breakdown of cellulosic material, and possibly plastics and other synthetic materials, will produce mainly CO2, but also other gases. The rate of microbial gas production will depend upon the nature of the microbial populations established, the prevailing conditions (temperature, pressure, geochemical conditions), and the substrates present. [WFMisc]		The inventory of organic material in the emplacement drifts at closure will be limited, such that the potential gas formation will be minor (CRWMS M&O 2000k, Section 6.4). CO2 will be produced by microbial activity, but this would tend to increase the CO2 fugacity.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.12.05.00	Gas generation from concrete	Production of gases from the aging and degradation of concrete may occur through radiolysis of water in the cement pore spaces and microbial growth on concrete.		Cementitious materials will be limited to rockbolt grout, and rockbolts will be used in only a portion of the repository (CRWMS M&O 2000k, Section 6.3). Radiolysis of the cement grout will be limited because of declining radiation flux, and shielding by the host rock. Any gas produced will tend to be diluted and dispersed in the drift openings and the host rock such that the consequences are likely to remain negligeable (Section 6.2).
2.1.12.06.00	Gas transport in waste and EBS	Gas in the waste and engineered barrier system could affect the long-term performance of the disposal system. Radionuclides may be transported as dissolved gases or in gas bubbles. These may affect flow paths, and two-phase flow conditions may be important. [WFMisc]		Gas bubbles will not form, or will not be mobile, in the unsaturated environment. Certain radionuclides could be gaseous but will be volumetrically limited compared to the gas-phase flux through the drift openings (CRWMS M&O 2000k, Section 6.2).
2.1.12.08.00	Gas explosions	Explosive gas mixtures could collect in the sealed repository. An explosion in the repository could have radiological consequences if the structure of the repository were damaged or near-field processes enhanced or inhibited. [WFMisc]		Any flammable gas produced will tend to be diluted and dispersed in the drift openings and the host rock, because of the flux of water vapor and air that is likely to occur (CRWMS M&O 2000k, Section 6.2).

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.1.13.01.00	Radiolysis	Alpha, beta, gamma and neutron irradiation of water can cause disassociation of molecules, leading to gas production and changes in chemical conditions (Eh, pH, concentration of reactive radicals). [WP, WFMisc]		The absorbed radiation energy in the EBS will be limited because the gamma flux will decay sharply with time. Only a portion of the overall production of chemical species by radiolysis will access the waste package surface. Radiation dose levels at the waste package surface are smaller in the current design, than previous estimates (Van Konynenburg 1996, Wilder 1996).
2.1.13.02.00	Radiation damage in waste and EBS	Strong radiation fields could lead to radiation damage to the waste forms and containers (CSNF, DSNF, DHLW), backfill, drip shield, seals and surrounding rock. [WP, WFMisc]		Ex-container gamma radiolysis may occur, but decreases steeply in early time (e.g. 400 years). Analysis has shown that neutron embrittlement of EBS materials will not be important, (CRWMS M&O 2000kk, Section 6.3.5, reference design analysis on embrittlement).
2.2.07.06.00	Episodic/ pulse release from repository	Episodic release of radionuclides from the repository and radionuclide transport in the UZ may occur both because of episodic flow into the repository, and because of other factors including intermittent failures of waste packages. Note that this FEP also encompasses FEP ebs # 16 from table 3 [see EBS FEP AMR Rev00, table did not transfer, see FEP 2.2.07.06.00]. [UZ]	Water diversion and drainage response of the EBS has been evaluated over a range of infiltration/seepage conditions (CRWMS M&O 2000i, Section 6.1). Increased infiltration/seepage associated with climate change is included in models for TSPA and evaluation of FEPs (CRWMS M&O 2000m, Section 6.12). Thus some changes in percolation and seepage are included in current models.	For linear sorption, changes in water-solid ratio cause changes in solute partitioning that are compensated by changes in dilution. The result is that release rates would vary but concentrations would not. Many of the available data for radionuclide sorption are interepreted in terms of linear distribution coefficients.

Table I-1. Preliminary EBS Process Model FEP Screening Considerations (Continued)

YMP FEP #	FEP Name	Database Rev 00 EBS FEP Description [Other PMRs Addressing FEP]	EBS Process Model Considerations for TSPA (References in Parentheses)	
2.2.08.04.00	Redisso-lution of precipitates directs more corrosive fluids to containers	Redissolution of precipitates that have plugged pores as a result of evaporation of groundwater in the hot zone, produces a pulse of fluid reaching the waste containers when gravity-driven flow resumes, which is more corrosive than the original fluid in the rock. [NFE, UZ]	Models for water composition in the EBS that are used for TSPA and evaluation of FEPs, include waters that are evaporatively concentrated, similar to what could result if dilute waters encounter previously deposited precipitates and salts (CRWMS M&O 2000k, Section 6.7).	
2.2.11.02.00	Gas pressure effects	Pressure variations due to gas generation may affect flow patterns and contaminant transport in the geosphere. [UZ]		Gas generation will be dominated by evolution of water vapor. The high-permeability host rock will not permit significant increase in total gas-phase pressure, as can be inferred from TH model results (CRWMS M&O 2000i, Section 6.3; CRWMS M&O 2000m, Section 6.12). It is likely that the rate of water vapor production during the thermal period (CRWMS M&O 2000k, Section 6.2) will exceed production rates for gases that could ever be produced from other sources. In other words the evaporation of water exceeds gas production from chemical reaction (the mass of water greatly exceeds the available mass of reactants) and biological activity.